NEUROPSYCHOLOGICAL AND ADAPTIVE SKILLS DEFICITS IN CHILDREN WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER WITH AND WITHOUT COMORBID FETAL ALCOHOL SPECTRUM DISORDER

A DISSERTATION

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BY

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Abstract

The majority of children with Fetal Alcohol Spectrum Disorder (FASD) have comorbid Attention-Deficit Hyperactivity Disorder (95%; Fryer et al., 2007). The goal of this study was to compare the neuropsychological and adaptive skills profiles of children with Attention-Deficit/Hyperactivity Disorder (ADHD) with or without comorbid FASD in order to improve interventions for both of these populations. This study paid particular attention to neurological, cognitive, and adaptive skills strengths and weaknesses in children with ADHD/FASD and children with ADHD without comorbid FASD. By identifying these strengths and weaknesses recommendations were able to be made to help the functioning of each of children with ADHD/FASD and children with ADHD in their home, community, and school environments based on their neuropsychological and adaptive skills profiles.

Neurologically, children with ADHD/FASD and children with ADHD have been shown to have impairment in the basal ganglia, cerebellum, corpus callosum, frontal lobes, hippocampus, hypothalamus, occipital lobes, parietal lobes, temporal lobes, and thalamus. Cognitively, children with ADHD have been shown to have difficulty in areas such as working memory and processing speed with less significant deficiencies in verbal ability and perceptual organization whereas children with ADHD/FASD have shown

impairment in all of these cognitive abilities. When compared to typically developing children with approximately the same level of general intelligence, children with ADHD have been shown to obtain lower standard scores in all domains of adaptive functioning and children with FASD have been shown to demonstrate significant adaptive skills deficits throughout the lifespan.

This study used specialized statistical procedures including Multivariate Analysis of Variance (MANOVA), Discriminant Analysis (DA), and Classification and Regression Tree (CART) in order to investigate the neuropsychological and adaptive skills in 81 children with ADHD/FASD and 147 children with ADHD. The statistical analyses indicated that children with ADHD/FASD and children with ADHD have similar cognitive and adaptive skills profiles; however, the children with comorbid ADHD/FASD were significantly more impaired in verbal ability, perceptual reasoning, working memory, processing speed, and overall adaptive skills.

The current study took a step forward in helping to make diagnostic decisions based on the similarities and differences between children with ADHD with and without comorbid FASD. Given the data from the current study indicating the significant differences in cognitive and adaptive skills in these two samples, it is imperative that psychopharmacological interventions be tailored to these two seemingly similar yet different groups, especially as these two groups may respond differently to stimulant medication, the first line of medicinal treatment for ADHD. Children with ADHD/FASD should also be treated with more intense interventions in the home, community, and school than children with ADHD.

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Several years ago when I entered my first year in the Ball State School Psychology Ph.D. program I was completely dedicated to the upcoming work that earning my Doctoral Degree would entail. One thing I did not realize at that time was how much work, commitment, and sacrifice would be required by other individuals in my life during my pursuit. I would like to give sincere thanks to the following people for their continued support and dedication. First of all, I would like to thank my loving, caring, and patient wife Macey Boseck and our beautiful daughter, Payten Boseck. These last few years have been a challenge given the amount of time I have dedicated to my graduate school career. Thank you both so much for being so understanding and supportive throughout this whole process; I love you both very much. Next, I would like to thank Dr. Andrew Davis for his support and guidance throughout my graduate studies. I have learned a tremendous amount about psychology, neuropsychology, and work ethic based on your example and advice. I would like to give special thanks to Dr. Jerrell Cassady for all of your support throughout graduate school. I would like to thank all of my committee members including Drs., Andrew Davis, Jerrell Cassady, Carrie Ball, and Roger Wojtkiewicz for their guidance throughout the preliminary examination and

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Vitae

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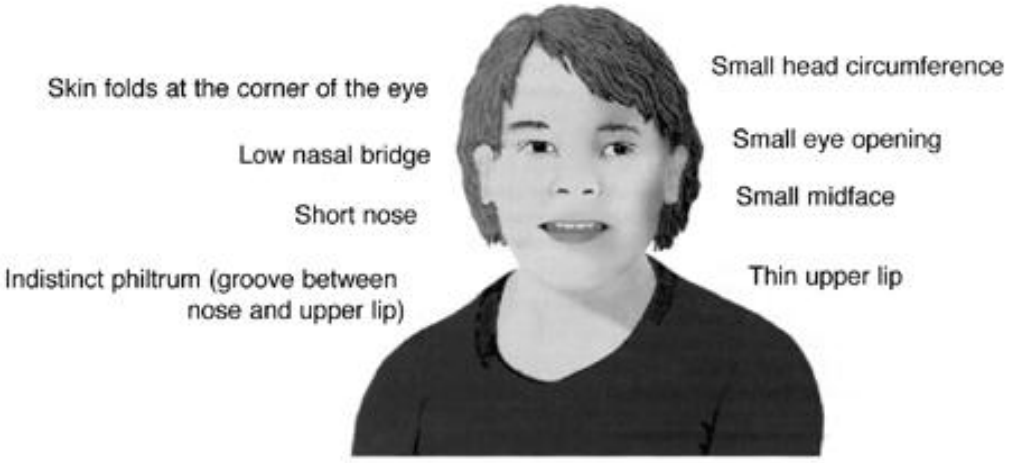
Chapter 1

Introduction

Fetal Alcohol Spectrum Disorder. Fetal Alcohol Syndrome (FAS) was first recognized in 1973 (Jones & Smith, 1973) when Kenneth Lyons Jones and David Smith described 11 children born to alcohol-abusing mothers (Jones et al., 1973). According to the Institute of Medicine (IOM; Stratton, Howe, & Battaglia, 1996), full FAS criteria includes; (1) a positive history of prenatal alcohol exposure, (2) craniofacial anomalies (including any of the following; flat midface, thin upper lip, epicanthal folds, smooth or flattened philtrum, underdeveloped jaw, low nasal bridge, small eye openings, and/or a short nose), (3) pre and/or postnatal growth deficiency (these may be referred to as small for gestational age, low birth weight to height ratio, or short stature), and, (4) central nervous system (CNS) dysfunction including physical (decreased cranial size at birth, structural brain abnormalities, and neurological hard or soft signs such as impaired fine motor skills, neurosensory hearing loss, poor tandem gait, and/or poor hand-eye coordination) or behavioral dysfunction (i.e., hyperactivity, mental retardation, social problems).

Diagnosis of FAS can be difficult due to the lack of mothers who self-report alcohol use during pregnancy as well as the relatively high adoption rate among children prenatally exposed to alcohol which can result in difficulty establishing biological maternal alcohol use during pregnancy. Therefore, one of the most highly useful clinical techniques for diagnosing FAS is facial structure analysis. As Davis (2006) indicated, identifying markers in children with neurological disorder (such as FAS) may help lead to earlier diagnosis and thus more successful interventions.

The craniofacial anomalies indicative of FAS are presented here as demonstrated by Warren and Foudin (2001):



To acknowledge the continuum of deficits caused by prenatal alcohol exposure, the National Task Force on Fetal Alcohol Syndrome and Fetal Alcohol Effects adopted the term ‘Fetal Alcohol Spectrum Disorder’ (Bertrand et al., 2005). Currently, FASD is not a diagnostic category, but an umbrella term used to emphasize the range of deleterious physical, mental, and behavioral outcomes that can occur after intrauterine exposure to alcohol. Fetal Alcohol Syndrome falls at the severe end of the FASD continuum (Mattson & Vaurio, 2010).

The Institute of Medicine (IOM; Stratton, Howe, & Battaglia, 1996) suggested the diagnosis of FASD includes confirmed exposure to intrauterine alcohol exposure, plus any one or a combination of the following; (1) craniofacial anomalies; (2) growth retardation; (3) evidence of CNS dysfunction; or (4) evidence of a complex pattern of behavior or cognitive abnormalities that are inconsistent with developmental level and cannot be explained by familial background or environment alone such as learning difficulties, deficits in school performance, poor impulse control, problems in social perception, deficits in higher-level receptive and expressive language, poor capacity for abstraction or metacognition, specific deficits in mathematical skills, or problems in memory, attention, or judgment (Stratton, Howe, & Battaglia, 1996).

In 1994, FAS was generally accepted to occur in the offspring of alcoholic women, that is, women who drank at least six standard drinks per day throughout the first trimester (one standard drink = 12 oz beer = 5 oz glass of wine = 1.5 oz liquor or approximately 0.5 oz of absolute alcohol; Schneiderman, 1994). Government studies conducted in 2004 indicated that 1 in 12 pregnant women drank and about 1 in 30 women reported binge drinking (more than 5 drinks on any one occasion; SAMHSA, 2004) during pregnancy. However, according to May and Gossage (2001), only 10% to 40% of women who chronically abuse alcohol during pregnancy will give birth to a child with FAS.

According to May and Gossage (2001), the incidence of FAS is 0.5 to 2 per 1000 live births. These rates equate to current incidence estimates of 1,000 to 6,000 infants with FAS born each year in the United States (Bertrand et al., 2005). However, the incidence of FASD may be as high as 1 per 100 live births (May & Gossage, 2001) which

is even greater than the most recent estimates of autism spectrum disorders (ASDs) which are estimated to occur in 1:110 children (CDC, 2009). The Centers for Disease Control (CDC) concluded that there were over 4 million births in 2005 (4,138,439; Centers for Disease Control; 2007), which means that there may be up to 40,000 children born every year in the United States with FASD.

Attention-Deficit/Hyperactivity Disorder. The behavioral syndrome of ADHD has been recognized since the early 1900s. The features of this syndrome gradually emerged from observations over many years from professionals working in pediatric medicine, neurology, education, and pharmacology (Conners, 1998). The diagnostic criterion for ADHD has undergone numerous alterations since its first inception. The current criteria include three subtypes of ADHD which include: ADHD, Predominantly Inattentive Type; ADHD, Predominantly Hyperactive/Impulsive Type; and ADHD, Combined Type. Each of these disorders differs in presentation based upon varying degrees of disinhibition, inattentiveness, impulsivity, and hyperactivity.

According to the DSM-IV-TR (APA, 2000), ADHD is diagnosed as a function of inattention, hyperactivity, and impulsivity. The inattentive features of ADHD include difficulty paying close attention to details, difficulty with sustained attention, not listening when spoken to directly, not following through on instructions, difficulty with organization, avoidance of tasks requiring sustained attention, losing things necessary for tasks, distractibility, and forgetfulness. The hyperactive features of ADHD include fidgeting, leaving one's seat at inappropriate times, running around at inappropriate times, difficulty engaging in activities quietly, being often "on the go," and talking excessively. The impulsive symptomatology includes often saying answers to questions

before the question has been finished, difficulty waiting one's turn, and interrupting others during conversation.

It has been stated that approximately 5% of children meet the diagnostic criteria for ADHD (APA; 2000). In virtually all community samples, the proportion of individuals who meet DSM-IV-TR symptom criteria for ADHD, Predominantly Inattentive Type (approximately 50% across all samples) is higher than the proportion who meet symptom criteria for ADHD, Predominantly Hyperactive/Impulsive Type (20%) or ADHD, Combined Type (30%; Willcutt et al., 2005). In contrast, samples recruited through clinics typically include a much higher proportion of individuals with the combined subtype (approximately 60% across samples) than the inattentive (30%) or hyperactive-impulsive subtype (10%; Willcutt, 2010).

In order for ADHD to be diagnosed, symptoms have to be present previous to 7 years old; and impairment must be observed in 2 or more settings that affect functioning in some manner for a minimum of 6 months (APA, 2000). It is difficult to establish the diagnosis in children younger than age 4 or 5 years because their characteristic impulsivity, difficulty with attention, and sometimes overly active behavior is more typical in this age range (APA, 2000). Furthermore, although the onset of ADHD usually occurs before the age of 4, it is most commonly diagnosed when a child enters school due to the identification of symptoms in comparison with same-aged peers.

According to the APA (2000), symptoms of ADHD are typically at their most prominent during the elementary grades. As children mature, symptoms usually become less conspicuous. By late childhood and early adolescence, signs of excessive gross motor activity (e.g., excessive running and climbing, not remaining seated) are less

common, and hyperactivity symptoms may be confined to fidgetiness or an inner feeling of jitteriness or restlessness (APA, 2000).

The disorder is more frequently diagnosed in males than in females, with male-to-female ratios ranging from 2:1 to 9:1 (APA, 2000) depending on the ADHD subtype and setting in which the diagnosis is made. Research has shown that girls are more likely to be diagnosed with ADHD, Predominantly Inattentive Type while boys are more likely to be diagnosed with ADHD, Predominantly Hyperactive/Impulsive Type or Combined Type. Clinic-referred children are also more likely to be male (APA, 2000). Symptoms of hyperactivity, impulsivity, and inattentiveness usually appear in multiple settings and are required in at least two settings in order for an ADHD diagnosis to be made. However, fluctuation in these behavioral manifestations of the disorder may be present depending upon the demands of the situation the child is in. Moreover, signs of the disorder may be minimal or absent when the child is receiving frequent rewards for appropriate behavior, is under close supervision, is in a novel setting, is engaged in especially interesting activities, or is in a one-to-one situation (e.g., a clinician's office; APA, 2000).

No single cause of ADHD has been discovered (Conners, 1998). Rather, a number of significant risk factors affecting neurodevelopment and behavioral expression have been suggested to correlate with ADHD such as genetic factors and epigenetic causes including maternal alcohol, tobacco, and drug use while pregnant. Several of these risk factors lead to the assumption that the disorder frequently reflects a summation of independent forces impinging on early development (Biederman et al., 1998; Conners, 1998). Neurodevelopmental and behavioral expression of ADHD can lead to many deficits including neuroanatomical, neuropsychological, cognitive, adaptive, and

behavioral deficits. The field of psychology is not yet at the point at which etiological markers can be identified and used to improve clinical diagnosis and treatment, but neuropsychological research has the potential to facilitate important advancements in these areas by helping to pinpoint the specific neural systems that are compromised in ADHD (Willcutt, 2010).

Clinical Implications of a Link between ADHD and FASD. The similarity in clinical presentation of children with ADHD and children with FASD is extensive as it has been shown that up to 95% of those with FASD also have ADHD (Fryer et al., 2007). There are many similarities and differences between children with ADHD/FASD and ADHD without FASD (hereby referred to as children with ADHD). First, O'Malley and Nanson (2002) suggested that ADHD/FASD is a particular clinical subtype of ADHD with an earlier onset and dissimilar clinical and neuropsychological presentation (O'Malley & Nanson, 2002) from the other current ADHD subtypes To further support this hypothesis, O'Malley and Nanson (2002) suggested that FASD is a chronic neurodevelopmental and neuropsychiatric disorder, and proper treatment of ADHD/FASD offers an opportunity to decrease its documented destructive secondary disabilities (O'Malley & Nanson, 2002) which may be more extensive for children with ADHD/FASD than for those children with ADHD.

Finally, it has been shown that patients with FASD have neurochemical and structural changes in their CNS, and are often overly sensitive to the side effects of medication (O'Malley & Nanson, 2002). Therefore, investigating the neuropsychological profiles of those with ADHD/FASD will help in differential diagnosis as well as improve outcome measures through therapeutic and psychopharmacological interventions.

Rationale of the Study

Due to the significant overlap in symptomatology between children with ADHD and children with FASD, the goal of this investigation will be to compare neuropsychological and adaptive skills deficits for children with comorbid ADHD/FASD with a group of children with ADHD. Recent research has suggested a link between these disorders (Crocker et al., 2009; Herman et al., 2008; O'Malley et al., 2002; Rodriguez et al., 2009) and the most severe form of FASD, FAS, is currently being considered for addition into the DSM-V (DSM5.org). An empirical investigation comparing those with ADHD/FASD to those with ADHD will provide evidence regarding the neurocognitive profile of children with ADHD/FASD, and therefore help to improve the differential diagnosis and treatment options for these children. An analysis of the similarities and differences in cognitive and adaptive skills deficits between children with ADHD/FASD and ADHD has not yet been fully explored. Investigating the neuropsychological profile of children with ADHD/FASD will facilitate the development of clinical, psychopharmacological, and intervention procedures and techniques for this population (e.g., O'Malley & Nanson, 2002).

The rationale for conducting such an investigation stems from the significant comorbidity between ADHD and FASD. Given this overlap, there must be something inherently similar in the manifestations of these disorders. The proposed link between ADHD and FASD is based on the premise that the teratogenic effects of prenatal alcohol exposure disturbs the environment of the developing fetal brain which can cause children exposed to alcohol in utero to present with a difficult-to-settle or slow-to-warm-up temperament, followed by early-onset ADHD (O'Malley & Nanson, 2002). Another

possible explanation for the link between ADHD and FASD is that women who have ADHD tend to drink alcohol more than women who do not have ADHD (Streissguth, 1997). Therefore, the children born to women with ADHD may have a genetic predisposition to ADHD as well as a higher probability of having FASD given their mother's higher rate of potential to drink while pregnant (O'Malley & Nanson, 2002).

Further investigation into the similarities between ADHD and FASD yield a genetic link between the disorders. Molecular genetic studies have found that there are specific dopamine genes associated with ADHD (Barkley, 2006). Genetic studies have revealed an association between the dopamine transporter gene (DAT) and the ADHD, Primarily Hyperactive/Impulsive subtype, and, similarly, between the dopamine D4 receptor gene and the ADHD, Primarily Inattentive subtype (Cook et al., 1995; Lahoste et al., 1996; O'Malley & Nanson, 2002; Stevenson, 1992). Likewise, the same dopaminergic system that is affected in ADHD is greatly impacted by prenatal exposure to alcohol, along with the noradrenergic, serotonergic, cholinergic, glutaminergic, GABAergic, and histaminergic systems (Druse, 1992); and it is postulated that the deficits in the dopaminergic systems of those children with FASD may be contributing to their ADHD symptomatology.

Attention-Deficit/Hyperactivity Disorder and FASD also appear to be hierarchically related. Attention-Deficit/Hyperactivity Disorder comorbid with FASD appears to be manifested as a more severe and debilitating form of ADHD. As O'Malley and Nanson (2002) indicated, the early onset, CNS dysfunction, complex learning disability, atypical medication response, and complicated psychiatric and medical comorbidity of children with FASD have many implications for management that

distinguish children with ADHD/FASD from those children with ADHD. This greater level of impaired functioning in individuals with ADHD/FASD may be due to the effects of intrauterine alcohol exposure.

Research has shown that children with FASD appear to have far greater impairment in overall intellectual functioning as well as more adaptive skills deficits than children with ADHD. This leads to the assumption that there is a greater impact on the overall structure and functional presentation of the neuroanatomical deficits seen in the ADHD/FASD group as opposed to the ADHD group. However, a systematic investigation into the similarities and differences in neuropsychological impairment between these two groups has not yet been conducted. Therefore, the goal of the current study will be to quantify the functional impact on the neuropsychological, cognitive, and adaptive functioning that the genetic and neuroanatomical deficits have on children with ADHD/FASD compared to those with ADHD.

This study will use observational reports of adaptive skills as well as direct measurement of cognitive ability to assess the differences between children with ADHD/FASD and those with ADHD. Investigation of cognitive and adaptive skills deficits will be undertaken in this study using the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003a) and the *Vineland Adaptive Behavior Scales* (VABS; Sparrow, Balla, & Cicchetti, 1984). These two measures are widely considered the gold standards of cognitive and adaptive skills, respectively, in the field of child psychological assessment. Validity studies have been conducted between the VABS and the WISC-IV. According to Sparrow and colleagues (2005), on average, the overall level of adaptive behavior functioning as measured by the VABS is very

similar to the Full Scale IQ from the WISC-IV (Sparrow, Cicchetti, & Balla, 2005) for the pediatric samples used in their validity and reliability studies.

The rationale for conducting the current study is further strengthened by previous research on the neuroanatomical, neuropsychological, cognitive, adaptive, and behavioral skills deficits in children with ADHD and FASD separately. However, due to the lack of investigation into the comorbid ADHD/FASD group, the extent of these impairments has not been quantified in a manner that best explains hallmark symptomatology that may be present in children with ADHD/FASD as compared to those with ADHD. Clinically, this research question can hold great significance due to the fact that there is such a significant rate of comorbidity of ADHD in children with FASD. Moreover, a diagnosis of FASD can be difficult when physical signs of prenatal alcohol exposure are not present and an extensive history is not available. However, a comprehensive examination of the deficits seen in children with comorbid ADHD/FASD against those with ADHD may provide a more parsimonious method for clinical diagnostic and intervention decisions when physical signs and an extensive history is not available.

Significance of the Study

Given the severity of deficits seen in children diagnosed with ADHD and FASD separately, a neuropsychological approach investigating all aspects of functioning in these clinical populations is necessary to help improve everyday functioning. As Davis and colleagues (2006b) pointed out, individuals with significant neurological impairment often have problems with attention, concentration, verbal skills, motor skills, and executive functioning (EF). All of these deficits have been noted in both the ADHD and FASD populations. Therefore, it is imperative to begin advancing the investigation into

the impairments seen in children with ADHD/FASD and ADHD in all of these areas and begin to correlate the significant differences in deficits between these groups in order to advance diagnostic, psychopharmacological, and intervention techniques (O'Malley & Nanson, 2002). As numerous researchers have pointed out, neuropsychological assessment incorporates numerous fields of research in order to best explain behavior. It is through a neuropsychological approach that proper investigation can be conducted in order to differentiate children with ADHD/FASD and those with ADHD.

The investigation of cognitive deficits in children with ADHD/FASD is a topic that is still in need of research and is of vital importance for these children's functioning in the academic, home, and community environments. According to Rasmussen (2005), the cognitive deficits in children with FASD are not fully understood, and exploring these deficits is invaluable for enhancing our knowledge of the neuropsychological sequelae of individuals with FASD, and, ultimately, for improving diagnosis and treatment. Differentiating those cognitive deficits seen in children with ADHD/FASD from those with ADHD will help in creating specific interventions in order to pioneer advancements in treatment for each of these groups. Furthermore, using a comprehensive cognitive skills evaluation, EF deficits can be investigated through such measures as working memory and processing speed. Rasmussen (2005) proposed that the field of FASD should begin focusing on studying the patterns of weaknesses in EF in order to enhance diagnosis, improve treatment, and help advance intervention techniques (e.g., O'Malley & Nanson, 2002).

Differences in adaptive skills deficits between children with ADHD/FASD and ADHD have not been investigated. A more thorough understanding of the cognitive, EF,

and adaptive skills deficits between children with ADHD/FASD and those with ADHD will help guide differential diagnosis, psychopharmacological treatment, as well as provide practitioners and caregivers the opportunity to cater interventions to cognitive, EF, and adaptive skills strengths and weaknesses for each of these populations.

The significance of investigating the similarities and differences between children with ADHD/FASD and ADHD include:

1. Improving psychopharmacological treatment for children with (separate subtypes of) ADHD.
2. Recognizing the ADHD/FASD population at an earlier age, therefore helping advance specifically-catered interventions for this population.

Psychopharmacological Treatment. Psychopharmacological treatment can be investigating the neurocognitive profile of ADHD/FASD and ADHD. It has been shown that those with comorbid ADHD/FASD have far different reactions to psychostimulant medication than those with ADHD. Children with FASD are often overly sensitive to the effects and side effects of medication due to the unique neurochemical and structural changes in the CNS (O'Malley & Nanson, 2002). In the University of Washington Secondary Disabilities Study (Streissguth et al., 1996), children with ADHD/FASD were given methylphenidate (i.e., Ritalin, Concerta) to reduce hyperactivity, impulsivity, and inattentiveness and only 47% had a successful response to the medication. Furthermore, O'Malley and colleagues (2000) found only a 22% response rate to methylphenidate in children with ADHD/FASD. In comparison, Schachter and colleagues (2001) conducted a meta-analysis in which they found that 70% of children with ADHD improved after methylphenidate treatment. In contrast, O'Malley and colleagues (2000) found that 79%

of children with ADHD/FASD improved with dextroamphetamine (Dexedrine) treatment. Therefore, in differentiating between ADHD/FASD and ADHD, psychopharmacological interventions can be improved as research shows that proper medications benefit up to 79% of children with properly diagnosed ADHD in treating the major symptoms of inattention, hyperactivity, and impulsivity (Greenhill et al., 2002).

Advancing Interventions. By investigating the neuropsychological profile of children with ADHD/FASD clinicians will be able to better serve this population. Currently, many children with FASD go unrecognized in the population due to the fact that most of them do not have mental retardation but still struggle with many neuropsychological and cognitive tasks. Therefore, by studying children with ADHD/FASD, this population may be more likely to be recognized and referred for psychological diagnosis, hopefully at an earlier age, and subsequent therapy and interventions based on their specific pattern of deficits can be suggested and implemented. Additionally, it has been shown that children with FASD are more likely to engage in law-breaking behavior all throughout their lives (Streissguth, 1997). Therefore, by recognizing this population at an earlier age and intervening before anti-social behavior can occur, the negative impact of the behaviors that some of these individuals may have on society may be reduced.

Finally, by investigating children with ADHD/FASD interventions can be implemented based on their specific neuropsychological profiles. Current research has suggested a link between ADHD and FASD; however, empirical research quantifying cognitive and adaptive skills strengths and weaknesses has not been conducted on children with ADHD/FASD, therefore, a neuropsychological profile for this population

has not been gathered. For that reason, through the current investigation as well as future research into this issue, children with ADHD/FASD can be helped through interventions based on their specific neuropsychological strengths and weaknesses.

Current Study

This study used an archival data set of children under the age of 18 with ADHD/FASD and ADHD that contains scores on the *Wechsler Intelligence Scale for Children – Fourth Edition* (Wechsler, 2003a) and *Vineland Adaptive Behavior Scales* (Sparrow, Balla, & Cicchetti, 1984). Current research investigating the strengths and weaknesses between these populations on the WISC-IV and VABS does not currently exist.

Research Questions

R_1 What is the profile of composite and subtest cognitive processing scores of the WISC-IV for those children with ADHD/FASD and children with ADHD?

R_2 Is there a significant difference on overall cognitive ability between those children with ADHD/FASD and children with ADHD?

R_3 Are there significant differences on cognitive skills measures between those children with ADHD/FASD and children with ADHD?

R_4 What is the profile of adaptive skills composite and domain scores of the VABS for those children with ADHD/FASD and children with ADHD?

R_5 Are there significant differences on adaptive skills measures between those children with ADHD/FASD and children with ADHD?

R_6 Which of the cognitive and adaptive skills composites contribute the greatest to the differences in functioning between those children with ADHD/FASD and children with ADHD?

R_7 What are the specific cognitive and adaptive skills deficits that most likely classify a diagnosis of ADHD/FASD or ADHD?

R_8 Does gender, prescription medication, and gender significantly account for the differences in functioning between the two diagnostic groups?

Limitations of the Study

One of the limitations of this study is in the inherent difficulty of estimating the impact of mother's use of other drugs during pregnancy. It has been found that using more than one substance is common among women who abuse drugs during pregnancy. One study found that half of pregnant illicit drug users also smoke and drink (Ebrahim & Groerer, 2003). This is a threat to internal validity as some of the deficits seen in children with FASD may be attributable to other drug use by mothers during pregnancy.

Additionally, deficits in children with prenatal alcohol exposure could be a result of alcohol's teratogenicity, environmental factors such as a chaotic home environment, or a synergy between prenatal alcohol exposure and environmental factors (Thomas et al.,

1998). Therefore, to conclusively assume a direct effect of alcohol on any type of behaviors in the clinical realm, a larger sample size and detailed measures of the home environment and parenting styles would be needed (Thomas et al., 1998). Therefore, the results from the current study may be partly due to other factors not associated with prenatal alcohol exposure.

External validity is also an area of concern. Another limitation of this study is that the selection of participants will all be from a rural/suburban Midwestern area. Therefore, the differences in diagnostic criteria from this region to other regions may reduce the generalizability of this study.

The data used from this study were collected from an archival database utilizing patient records between 2005 and 2009. Therefore, the data collected for these analyses may have been subject to errors due to changes in record-keeping and assessment scoring procedures. Archival data was also subject to error secondary to data collection procedures. Archival data were gathered from an outside source, scribed onto separate data collection sheets, and entered into a secure electronic database. Due to the amount of data transcription the amount of error in the data may be at a higher level. Finally, given that the data were gathered from an archival database, assessments conducted on the individuals in this study were subject to selective gathering procedures. Therefore, information such as who the children's caregivers were at the time of assessment was not able to be gathered. Another limitation of this study is that the original *Vineland Adaptive Behavior Scale* (Sparrow, Balla, & Cicchetti, 1984) was used to assess children when a newer version of the same scale was available, the Vineland Adaptive Behavior Scale –

Second Edition (Sparrow, Cicchetti, & Balla, 2005), which may lead to possible inadvertent inflation or deflation of scores on this measure (i.e., the Flynn Effect).

This study will be analyzing two groups; children with ADHD/FASD and children with ADHD. This study will not be analyzing scores on the WISC-IV or VABS from a control group. The standardization samples from each of these measures will serve as the control group.

Lastly, this study will use only those individuals under the age of 18. This appears to limit generalizability of these results across age ranges to older populations. However, it has been shown that the IQ scores of adolescents and adults are largely stable across the lifespan. Therefore, it is implied that deficits seen in the cognitive abilities, and possibly adaptive skills, of the samples in this study are not a limitation and the results of this study can be generalized to populations of all age ranges.

Delimitations of the Study

The greatest strength of this study is the large sample size of the two populations being studied. Fetal Alcohol Spectrum Disorder is a relatively difficult sample of patients to study given that it is not currently an official psychiatric diagnosis. Therefore, studying large samples of children with FASD is often difficult and the sample gathered in this study is well representative of this population.

Another delimitation of this study is in the psychometric validity of the assessments chosen. The WISC-IV and VABS are highly regarded clinical assessments used to gauge cognitive and adaptive skills in children in the field of neuropsychological evaluation. Also, the WISC-IV Indexes used to gauge EF deficits in this study are direct functional measures of EF. Previous studies have used subjective measures of EF to

quantify deficits in individuals with FASD. Therefore, the use of objective measures of EF makes this aspect of the study a replication and an important extension of previous research conducted in this area.

Another strength of this study is that this clinical sample of children with FASD were diagnosed as part of a comprehensive physiological and neuropsychological evaluation following the standards outlined in the 4-Digit Diagnostic Code (Astley & Clarren, 1999) for diagnosing FAS by a neuropsychologist specializing in neurodevelopmental disorders as well as a physician specializing in medical genetics and pediatric developmental disorders. Also, all children in this sample diagnosed with ADHD were diagnosed by the same neuropsychologist that helped to diagnose the children with FASD. Therefore, inter-rater reliability among diagnoses and assessment procedures were not an issue in the samples that will be studied in this investigation.

Finally, doubts have been raised about the current nosological sub-typing and the possibility that inattention and hyperactivity/impulsivity reflect separate disease entities (Barkley, 1998; Conners, 1998). This study used the ADHD, Combined Type which is a combination of the ADHD, Predominantly Hyperactive/Impulsive type and ADHD, Predominantly Inattentive type; therefore, negating the impact of possible arguments regarding the separate presentation of these two ADHD subtypes.

List of Terms

Adaptive Skills testing: Adaptive skills are often tested to analyze a patient's social, emotional, communication, daily living, and motor skills deficits. The *Vineland Adaptive Behavior Scales* (VABS; Sparrow et al., 1984) is one of the most commonly used

instruments in adaptive skills testing. This test identifies deficits in Communication (receptive, expressive, written), Daily Living (personal, domestic, community), Socialization (interpersonal relationships, play and leisure time, coping skills), and Motor Skills (gross and fine). This measure also has an Adaptive Behavior Composite standard score which is an amalgamation of all of the aforementioned adaptive skills. All of these composites have a mean of 100 and standard deviation of fifteen.

Attention-Deficit/Hyperactivity Disorder (ADHD): According to the APA (2000), ADHD consists of a persistent pattern of inattention and/or hyperactivity that is more often displayed and more severe than is typically observed in individuals at a comparable level of development. Some hyperactive-impulsive or inattentive symptoms that cause impairment must have been present before age seven, although many individuals are diagnosed after the symptoms have been present for a number of years, especially in the case of individuals with the Predominantly Inattentive Type. Some impairment from the symptoms must be present in at least two settings (e. g., at home and at school or work). There must be clear evidence of interference with developmentally appropriate social, academic, or occupational functioning. Finally, the disturbance does not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and is not better accounted for by another mental disorder (e.g., a Mood Disorder, Anxiety Disorder, Dissociative Disorder, or Personality Disorder; APA, 2000).

Agenesis of the corpus callosum: A congenital condition in which the corpus callosum, a bundle of nerves connecting the hemispheres of the brain, fails to develop.

Alcohol Related Birth Defects: The term alcohol-related birth defects (ARBD) has been used to describe fetal alcohol effects but has not proven to be clinically useful, as it is an umbrella term without specific criteria (Streissguth, 1997). Alcohol-related birth defects are now collectively referred to under the classification of Fetal Alcohol Spectrum Disorder (FASD).

Alcohol-Related Neurodevelopmental Disorder: A term used previously in conjunction with fetal alcohol effects to describe the central nervous system dysfunction of children prenatally exposed to alcohol. Alcohol-related neurodevelopmental disorder (ARND) is now included under the umbrella term Fetal Alcohol Spectrum Disorder (FASD).

Attention: A hypothetical process that either allows a selective awareness of a part or aspect of the sensory environment or allows selective responsiveness to one class of stimuli (Kolb & Whishaw, 2008).

Central nervous system: The part of the nervous system that is encased in the bones and includes the brain and spinal cord (Kolb & Whishaw, 2008).

Epicanthal folds: A prolongation of a fold of the skin of the upper eyelid over the inner angle or both angles of the eye (Merriam-Webster's Medical Dictionary, 2006).

Executive Functioning (EF): A set of cognitive abilities thought to be largely collected and processed in the frontal lobes. Early research on EF was primarily focused on higher level cognitive abilities such as concept formation, inhibition, and planning; however, more recent research has implicated higher level cognitive abilities as well as fundamental skills such as attention, perception, and language (Shunk et al., 2006). It is now widely regarded that EF constitutes such advanced cognitive processes as planning, abstract thought, judgment, goal-directed behavior, reasoning, and the ability to solve

novel problems (Davis, 2006). Executive functioning can be defined as the capacities that enable a person to engage successfully in independent, purposive, self-serving behavior (Lezak et al., 2004). It is believed that the study of EF is an indirect measurement of frontal lobe functioning.

Fetal Alcohol Effects: A term that was widely used to describe individuals with intrauterine alcohol exposure who exhibit only some of the attributes of fetal alcohol syndrome but do not fulfill the full diagnostic criteria. Fetal Alcohol Spectrum Disorder (FASD) is the current term used to describe children with fetal alcohol effects (Davis, et al., 2008).

Fetal Alcohol Spectrum Disorder: Fetal Alcohol Spectrum Disorder (FASD) is not currently a psychiatric diagnostic category, but an umbrella term used to emphasize the range of deleterious physical, mental, and behavioral outcomes that can occur after exposure to alcohol in utero; Fetal Alcohol Syndrome (FAS) falls at the severe end of this spectrum of outcomes (Mattson & Vaurio, 2010). Fetal Alcohol Spectrum Disorder includes individuals referred to as having Fetal Alcohol Syndrome (FAS), Fetal Alcohol Effects (FAE), Alcohol-Related Birth Defects (ARBD), and Alcohol-Related Neurodevelopmental Disorder (ARND).

Fetal Alcohol Syndrome (FAS): A condition caused by maternal alcoholism or heavy drinking during pregnancy and is the leading known cause of preventable mental retardation. All of the following features need to be present in order for full criteria of FAS to be met: history of intrauterine alcohol exposure; pre- and or postnatal growth deficiency; effects on the central nervous system (CNS) such as intellectual impairment,

developmental delays, and/or behavior problems; or changes in facial features such as a flattened midface, small jaw, or thin upper lip (Bellenir, 2000).

Frontal Lobe: The most anterior portion of the cerebral cortex. Executive functioning (EF) is thought to be housed in the prefrontal cortex (PFC) and frontal lobes, although they require input from the rest of the brain (Davis, 2006a; Shunk et al., 2006).

Hyperkinetic Disorder (HKD): Hyperkinetic disorder is largely considered the International Classification of Disease (ICD-10) equivalent of ADHD. Hyperkinetic disorder is characterized by early onset; a combination of overactive, poorly modulated behavior with marked inattention and lack of persistent task involvement; and pervasiveness over situations and persistence over time of these behavioral characteristics (World Health Organization; WHO, 2007).

Intelligence Quotient (IQ): A standard index of general cognitive ability. As originally formulated by Binet and named by Terman in 1916, the mental age as determined by standardized test procedures was stated as a proportion of chronological age and multiplied by 100 to give an index with a mean of 100 and a standard deviation of 16 (Sattler, 2001). Contemporary instruments have replaced this procedure with the "deviation IQ," which artificially establishes that the distribution of IQ in any age group has a mean of 100 and a standard deviation of 15 (in the case of the most commonly used Wechsler tests; Beaumont, Kenealy, & Rogers, 1999).

Locomotor function: Locomotor function requires support of the body against gravity, stepping, balancing while the weight of the body is transferred from one limb to another, and pushing forward (Kolb & Whishaw, 2008).

Maxillary hypoplasia: The name that dentists have given to the underdevelopment of the maxillary bones, which produces midfacial retrusion and creates the illusion of protuberance of the lower jaw (Merriam-Webster's Medical Dictionary, 2006). Maxillary hypoplasia has also been more commonly referred to as underbite.

Microcephaly: The medical term used in the middle of the 20th century to define a small head. Microcephaly is usually associated with intellectual deficits (Beaumont, Kenealy, & Rogers, 1999).

Mild Brain Damage: A diagnostic term for children who had normal (or near normal) intelligence but who nevertheless showed varying degrees of learning and behavior problems associated with brain dysfunction (Clements, 1966).

Minimal Brain Dysfunction: A term previously used to refer to what is now known as ADHD; it was characterized by dyslexia, dysgraphia, hyperactivity, and/or mental retardation.

Neurocognitive profile: A profile of cognitive strengths and weaknesses generated form a comprehensive neuropsychological assessment.

Neurodevelopmental disorder: A disease of the nervous system.

Neurogenesis: Development of nerves, nerve tissue, or the nervous system (Merriam-Webster's Medical Dictionary, 2006).

Neuroimaging: Techniques used to analyze the brain and its activities. Neuroimaging can also be helpful for locating brain injury. Techniques for neuroimaging include computed tomography (CT), diffuse optical imaging (DOI), event-related optical signal (EROS), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), electroencephalography (EEG), magnetoencephalography (MEG), positron

emission tomography (PET), and single photon emission computed tomography (SPECT; Lezak et al., 2004).

Neuronal migration: The movement of neurons. At the completion of neurogenesis, cell differentiation begins, which is the process in which neuroblasts become specific types of neurons (Kolb & Whishaw, 2008).

Neuropsychologist: A professional psychologist who applies principles of assessment and intervention based upon the scientific study of human behavior as it relates to normal and abnormal functioning of the central nervous system (APA Division 40, 2009).

Neuropsychology: The scientific study of the relationship between the brain and human behavior (Davis et al., 2009) and the clinical application of the knowledge of the brain and human behavior to human problems (APA Division 40; 2009). Neuropsychology is not a set of specialized tests, but a way of thinking about assessment data from a brain-behavior perspective; all tests are neuropsychological tests when viewed from the perspective that the brain is responsible for behavior and that test scores represent samples of behavior (Mayfield et al., 2009).

Neuroscience: Embryology, anatomy, physiology, biochemistry, and pharmacology of the nervous system (Kolb & Whishaw, 2008).

Neurotransmitters: Chemicals released by neurons that affect other neurons. Important examples include glutamate (the most abundant excitatory neurotransmitter), GABA (the most abundant inhibitory neurotransmitter), acetylcholine, dopamine, norepinephrine, and serotonin (Lezak et al., 2004).

Occipital lobes: General area of the cortex lying in the posterior portion of the head. The occipital lobes form the posterior pole of the cerebral hemispheres, lying beneath the

occipital bone at the back of the skull (Kolb & Whishaw, 2008). The occipital lobes are generally referred to as the visual processing centers of the brain.

Palpebral fissures: The space between the margins of the eyelids (Merriam-Webster's Medical Dictionary, 2006).

Parietal Lobe: The part of the brain that processes and integrates somatosensory and visual information, especially with regard to the control of movement (Kolb & Whishaw, 2008).

Philtrum: The vertical groove on the median line of the upper lip (Merriam-Webster's Medical Dictionary, 2006).

Processing Speed: Processing speed is a performance-related ability involving perceptual processing and speed as reflected in both mental and psychomotor performance (Sattler, 2001).

Temporal Lobes: An area of the cortex found laterally on the head. The multifunctional temporal lobes house the primary auditory cortex, the secondary auditory cortex, the limbic cortex, amygdala, and hippocampus. Three basic sensory functions of the temporal lobes include; processing auditory input, visual object recognition, and long-term storage of sensory input – that is, memory (Kolb & Whishaw, 2008).

Working Memory: A dynamic short-term memory storage system of limited capacity, used to hold information that is being processed (Baddeley, 1990).

Chapter 2

Review of the Literature

The following review is organized into two sections that are relevant to the investigation of the neuropsychological profile of children with ADHD/FASD and ADHD. The first section will detail the functional neuroanatomy of ADHD and FASD. The second section will be an overview of the functional deficits that may occur secondary to the neurological impairment associated with ADHD and FASD. These neuropsychological and cognitive deficits will be presented in a format outlining the WISC-IV Indexes of Verbal Comprehension, Processing Speed, Perceptual Reasoning, and Working Memory. Adaptive and behavioral skills deficits will be presented by examining the VABS Communication, Socialization, Daily Living Skills, and Motor Skills composites.

Functional Neuroanatomy of FASD and ADHD.

Fetal Alcohol Spectrum Disorder. Studying the neuropsychological deficits in children with FASD can help neuropsychologists better understand the cognitive and adaptive skills deficits seen in this population. A clear link exists between neurological dysfunction and psychopathology in children, as evidenced by research on the sequelae

of developmental childhood brain impairment, the neuropsychological investigation of children with psychiatric disorders, and neuroimaging research (Davis, 2006).

The brain is highly sensitive during gestation and intrauterine toxicity can significantly affect neurodevelopment during this period. According to O'Leary (2004), the critical period for the damaging neurological effects of heavy alcohol consumption occurs in the first 3-6 weeks of brain development and during the time that the brain has its final growth spurt. This means that alcohol is most dangerous to brain development during the first 3 months and last 2 months of pregnancy. During the last trimester, the brain undergoes rapid development, and high levels of alcohol exposure are likely to lead to nerve cell death. Just one occurrence of excessive drinking (defined as drinking for several hours in a single drinking episode) during the final trimester could be enough to damage the brain of the fetus (Ikonomidou et al., 2000).

Along with neuroanatomical dysfunction in individuals with FASD, impairment in neurochemical systems may occur due to prenatal alcohol exposure. However, unlike children with ADHD, who have been shown to only mainly have two brain neurochemical system deficits (dopamine and norepinephrine), the brain chemistry of children with FASD has been shown to be abnormal in numerous neurochemical systems (e.g., dopaminergic, norepinephrine, noradrenergic, serotonergic, cholinergic, glutamatergic, GABAergic, and histaminergic; O'Malley & Nanson, 2002). Deficits in the dopamine and norepinephrine systems likely relate to ADHD symptomatology in those children with prenatal alcohol exposure (O'Malley & Nanson, 2002).

Alcohol impairs release of the brain's main excitatory neurotransmitter, glutamate, while facilitating activity of its main inhibitory transmitter, GABA (Kalat &

Begeny, 2009). Consequently, many neurons receive much less net excitation than normal, and they react as if they had failed to form normal connections and die (Ikonomidou et al., 2000). Therefore, children with FASD have fewer neurons at birth, and the neurons they do possess have fewer connections. This is a significant finding in that these neural effects could impair cognitive, adaptive, and behavioral functioning in a myriad of ways in individuals with intrauterine alcohol exposure.

Attention-Deficit/Hyperactivity Disorder. Behaviors characterizing ADHD are assumed to be largely or entirely due to abnormal brain function (Carey, 1998) and the pattern of neuropsychological impairment associated with ADHD shows correspondence with findings of subtle anomalies in brain anatomy and neurochemistry (Tannock, 1998a; Tannock, 1998b). In order to investigate this neuroanatomical impairment in children with ADHD, neuroimaging procedures have been conducted. The consensus among specialists is that neuroimaging procedures are not yet sufficiently refined or standardized to be useful for definitive diagnosis of ADHD (Quinlan, 2009); however, neuroimaging has been shown to be efficacious in finding focal deficits in neuroanatomical dysfunction in children with ADHD. Along with functional neuroanatomical impairment in individuals with ADHD, research has shown that specific neurotransmitters may also be affected in these individuals. Papolos and Papolos (2002) stated that ADHD is a behavioral disorder that appears to have a strong genetic component involving dysregulation of the norepinephrine and dopamine neurotransmitter systems.

Norepinephrine may serve to bring an individual to an alert state in order to prepare the brain to deal effectively with a novel situation. Distractibility and the disruption of attentional focus, commonly experienced symptoms of ADHD, may be

related to disturbances in the norepinephrine system that affects the ability to sustain attention and mental effort (Ashton-Jones & Bloom, 1981; Papolos & Papolos, 2002). This idea is reinforced by the fact that many stimulant drugs that enhance attentional focus, such as Ritalin (Methylphenidate Hcl), increase norepinephrine release. Along with dysregulation of the norepinephrine system in individuals with ADHD, dopamine neurotransmitters have also been shown to be affected. Dopamine is the principal neurotransmitter responsible for physical movement, reward-motivated behaviors, and body temperature regulation (Papolos & Papolos, 2002). Abnormal variations in the activity of the dopamine system may result in marked variations in activity and pressured speech (Papolos & Papolos, 2002).

Further evidence supporting the role of the neurotransmitters norepinephrine and dopamine has been evidenced through the efficacy of psychopharmacological medication that implicates these neurotransmitters. Stimulants used in the treatment of ADHD have an affinity to dopamine and norepinephrine (Madras et al., 2005). These stimulant medications have been widely successful in reducing inattentive, hyperactive, and impulsive symptomatology in children with ADHD.

Neuroimaging and Neuropsychological Functioning Deficits in Children with FASD and ADHD. Evidence regarding functional deficits in children with Fetal Alcohol Spectrum Disorder and Attention-Deficit/Hyperactivity Disorder has shown impairment in most cortical areas.

Table 1.1 Neurological and Neuropsychological Deficits

Brain Region	Children with ADHD	Children with FASD
Basal Ganglia Motor abilities, Executive Functioning	• Volume reductions (Castellanos et al., Filipek et al., 1997; 1996; Seidman et al., 2005). • Alteration to basal ganglia circuits (Lezak et al, 2004).	• Reduced volume (Archibald et al., 2001; Mattson et al., 1992; Norman et al., 2009). • Set-shifting, inhibition, and spatial memory deficits (Mattson et al., 2001).
Cerebellum Motor Movement, Processing speed, Language, Working memory, Attention.	• Reduced volume and activity (Castellanos et al., 2002; Schultz et al., 2004). • Theoretical models of impairment (Castellanos et al., 2002).	• Reduced volume (Archibald et al., 2001; Mattson et al., 1992, 1994, 1996). • Learning and coordination difficulties (Wacha & Obrzut, 2007).
Corpus Callosum Relays verbal information between hemispheres, Problem-solving, Verbal fluency.	• Impairment and overall size reduction (Bush, 2009; Hill et al., 2003; Hynd et al, 1991; McNally, 2010; Paul et al., 2007).	• Changes in size and shape (Riley & McGee, 2005). • Attention, reading, verbal memory, EF, and social skills deficits (Mattson & Vaurio, 2010).
Frontal Lobes Executive Functioning, Language, Visual Information, Motor Control,	• Frontal lobe dysfunction (Barkley, 1997; 2006; Willcutt, 2010). • Reduced volume (Carey, 1998; Hill et al., 2003; Seidman et al., 2005). • Dopamine imbalances (Solanto, 2001).	• EF deficits (Mattson & Vaurio, 2010; Rasmussen, 2005). • Left (Archibald et al., 2001; Sowell et al., 2001) and overall dysfunction (Fryer et al., 2009).
Hippocampus Memory, Learning, Retention, Recovery.	• Neuroimaging showing hippocampal impairment (Plessen et al., 2006; Volkow et al., 2007).	• Left side of hippocampus smaller than the right (Wacha & Obrzut), • Overall size reduction (Astley et al., 2009; Autti-Ramo et al., 2002; Bhatara et al., 2002).
Hypothalamus Temperature, Emotion, Satiety, Circadian rhythm, Memory.	• Hypothalamic dopamine dysfunction (Volkow et al., 2009) • HPA axis dysfunction associated with impulsivity (Hong et al., 2003).	• HPA pathway deleteriously affected (Hellmans et al., 2007; Niccols, 2007). • Neuroimaging (Gabriel et al., 1998; Macri et a., 2006).
Occipital Vision	• Neuroimaging (Tian et al, 2007). • Visual sensory integration deficits (Nazari et al., 2010).	• Size reduction (Archibald et al., 2001; Sowell et al., 2002).
Parietal Process visual information, Integrate sensory information.	• Structurally altered (Cherkasova & Hechtman, 2009; Wang et al., 2007). • Poorer performance on right parietal functioning tasks (Aman et al., 1998).	• Decreased blood flow (Riikonen et al., 1999). • Less white matter density (Sowell, 2002; 2008a; 2008b). • Poorer performance on the VMI (Sowell et al., 2008b).
Temporal Lobes Language Reception and Expression, Auditory processing.	• Neuroimaging showing impairment (Kobel et al, 2010; Rubia et al., 2007).	• Neuroimaging (Sowell et al., 2001). • Categorical verbal fluency deficiency (Vaurio et al., 2008).
Thalamus Information relay Arousal, Consciousness, Affect, Memory	• Decreased activation (Tamm et al., 2006). • Attentional dysregulation (Banich et al., 2009).	• MRI has shown deficiencies (Clark et al., 2000; Henry et al., 2007; Mattson et al., 1994).

Cerebral Cortex Impairment in Children with FASD and ADHD. The cerebral cortex is the complex system essentially responsible for much of the human brain-behavior relationship. As Luria (1973) indicated, "Human mental processes are complex functional systems and are not localized in narrow, circumscribed areas of the brain, but take place through the participation of groups of concertedly working brain structures, each of which makes its own particular contribution to the organization of this functional system." The cerebral cortex is the outer layer of the brain and over 80% of the cortex in humans serves an association function specially related to integrative and cognitive activities such as language, calculation, planning, and abstract reasoning (Afifi & Bergman, 1998). Impairment in the cerebral cortex can lead to dysfunction in cognition and behavior in children with ADHD and children with FASD.

Neuroimaging studies in children with FASD have found reduction of overall brain size (Archibald et al., 2001; Johnson et al., 1996; Mattson & Vaurio, 2010). Likewise, studies investigating children with ADHD have found smaller overall brain volume in every area studied (Castellanos et al., 2002). Consistent findings in neuroimaging investigations of large-scale cerebral dysfunction can have highly deleterious effects on functioning due to the fact that theories regarding localization of function have largely been replaced by theories on the interconnectedness of the brain in most processes. As Davis (2006) pointed out, most modern neuropsychological processing theories venture beyond the simple localization of impairment approach to embrace the interconnectedness of different brain areas (e.g., Luria, 1973). Moreover, although much research has focused on specific areas of deficits, with increasing neurobehavioral data and complementary findings, it appears that children with brain

damage have domains of functional vulnerability corresponding to differential brain involvement (Mattson & Vaurio, 2010). Therefore, although many areas of the brain must work together in order for complex behavior to occur; focal deficits in any area of the brain can lead to significant impairment due to the high level of interconnectedness among areas of the brain when behavior is produced.

Frontal Lobe Dysfunction in Children with FASD and ADHD. The frontal lobes are the anterior-most area of the cerebral cortex. The frontal lobes represent approximately 30% of the cortical surface (Miller, 2007). It was once believed that the frontal lobes were unitarily implicated in a variety of functions; however, it is now believed that functioning derived from the frontal lobes depends on specific areas of the frontal lobes such as the motor, premotor, and prefrontal regions. Furthermore, the frontal lobes have also been broken down into the left and right hemispheres with the left usually being dominant for language and the right being dominant for visual information. Although the frontal lobes are widely variable in function based on location, research into the frontal lobes of children with FASD or ADHD has not made such distinctions; however, it is assumed that local areas representative of motor, premotor, and prefrontal functions are implicated in functioning deficits. Large bodies of research have shown deficits throughout the frontal lobes for children with FASD and children with ADHD.

Executive functioning has long been thought to be housed in the frontal lobes, or more specifically, the prefrontal cortex (PFC; Willcutt, 2010). Executive functioning includes such processes as planning, organization, inhibition, and attention. Therefore, PFC dysfunction is thought to negatively impact EF (Brown, 2005; 2009). This is often

visible in children affected by either FASD or ADHD as they will often have difficulty with tasks that require planning, organization, inhibition, and attention.

A variety of studies examining children with ADHD utilizing various neuroimaging technologies have demonstrated impairments in the frontal lobes and PFC (Carey, 1998; Hill et al., 2003; Seidman et al., 2005). Structural magnetic resonance imaging (MRI) studies that measured frontal regions reported reduced volume in the PFC in children with ADHD (Seidman, et al., 2005). A child with damage to the prefrontal lobes will be more prone to reckless and impulsive behavior; will seem distractible and disorganized; may fail to develop a large wealth of knowledge; and may display motoric restlessness (Papolos & Papolos, 2002). Based on the similarities between ADHD symptomatology and the behavioral sequelae of frontal lobe injuries (e.g., Fuster, 1997), one of the most prominent theories of ADHD suggests that symptomatology arises from a primary deficit in EF (e.g., Barkley, 1997, 2006; Willcutt, 2010) which may derive from frontal lobe dysfunction. Furthermore, Barkley (2006) pointed out that evidence continues to mount that ADHD is associated, at least in part, with structural and/or functional differences in the frontal lobes.

Much like the research on children with ADHD, results from neuroimaging studies have indicated highly reduced brain growth in the frontal lobes in children with FASD, which was most prominent in the left hemisphere (Archibald et al., 2001; Sowell et al., 2001). Furthermore, abnormalities have been noted in the frontal lobes in neuroimaging studies by Fryer and colleagues (2009). Neuropsychological research on EF and measures of attention has also indicated frontal lobe dysfunction in children with FASD (e.g., Hill et al., 2003; Mattson & Vaurio, 2010; Rasmussen, 2005).

The frontal lobe abnormalities in children with ADHD and FASD suggest that many areas of functioning may be impacted such as those tasks requiring EF. Many abstract functioning processes require intact EF in order to be successful; therefore, dysfunction of the frontal lobes can have far-reaching negative effects for children with ADHD/FASD.

Temporal Lobe Impairment in Children with FASD and ADHD. The temporal lobes are located laterally in both the left and right hemispheres. The temporal lobes are critical components in language processing. They are also the areas of the brain that are highly involved in auditory processing as they contain the primary auditory cortices on each side of the brain.

Results of neuroimaging studies conducted by Sowell and colleagues (2001) found that prominent abnormalities were identified in the perisylvian cortices along the temporal lobes in children exposed to alcohol during pregnancy. This suggests that children with FASD may have difficulty with language expression and reception. Research on neuropsychological functioning conducted by Vaurio and colleagues (2008b) found that children with FASD had significantly poorer performance on the *Wisconsin Card Sorting Test* (WCST; Heaton et al., 1993), a measure of cognitive flexibility, working memory, attention, and visual-spatial ability. This finding is significant in that these investigators indicated that children with FASD were impaired on categorical verbal fluency whereas those with ADHD were not, suggesting the possibility of additional abnormalities in temporal regions in those children with FASD compared to those with ADHD. However, recent neuroimaging research (e.g., Kobel et al., 2010) has implicated the temporal lobes as an area of impairment in children with ADHD.

Furthermore, fMRI was used by Rubia and colleagues (2007) in a study investigating neuroanatomical dysfunction in children with ADHD in which the temporal lobes were found to be an area of impairment in correlation with perceptual attention response variability.

Occipital Lobe Dysfunction in Children with FASD and ADHD. The occipital lobe is located at the posterior portion of the brain and contains the primary visual cortex. The occipital lobe is the visual processing center of the brain. Neuroimaging research on children with ADHD using EEG during a continuous performance task showed that visual sensory integration deficits were found (Nazari et al., 2010). Tian and colleagues (2007) also found that children with ADHD had enhanced activity in the occipital lobe during fMRI which could result in inattentiveness secondary to hypervigilance. Neuroimaging research by Archibald and colleagues (2001) and Sowell and colleagues (2002) investigating children with FASD also indicated that overall reductions in size were prominent in the occipital lobes.

Parietal Lobe Dysfunction in Children with FASD and ADHD. The parietal lobe is located directly superior to the temporal lobes, anterior and superior to the occipital lobe, and posterior to the frontal lobes. The parietal lobe has been suggested to process visual information as well as integrate sensory information. Recent investigations into the neuroanatomical dysfunction in children with ADHD suggest that the parietal lobes may be structurally and functionally altered in these children (Cherkasova & Hechtman, 2009; Rubia et al., 2008; Wang et al., 2007). Research on the neuropsychological functioning of children with ADHD has also shown impairment in the parietal regions. Aman and colleagues (1998) found that boys with ADHD performed poorer than controls on

measures of right parietal functioning including a visual-spatial cueing task, turning task, and spatial relations, which may be indicative of right parietal lobe dysfunction. The dysfunction in the parietal areas of the brain in children with ADHD suggests that these children may struggle on tasks that require visual processing and somatosensory functioning.

Sowell and colleagues (2001) found abnormalities in the perisylvian and parietal regions of children with FASD. Sowell and colleagues (2002; 2008a; 2008b) also found decreased cerebral blood flow in the parietal regions of children with FASD which Sowell and colleagues (2008b) attributed to possible poor performance on the Beery-Buktenica Visual Motor Integration task, a measure of visual motor skills. Likewise, Riikonen and colleagues (1999), in one neuroimaging study, found decreased cerebral blood flow in the left parietal region in children with FASD. Together, these findings suggest that children with ADHD/FASD and ADHD will likely have impairment on tasks that require processing visual information and integrating sensory information.

Cerebellar Dysfunction in Children with FASD and ADHD. The cerebellum, Latin for "little brain," is at the posterior base of the brain. The adult human cerebellum weighs approximately 150g (10% of brain weight) and has a surface area of approximately 1000cm^2 (40% of the cerebral cortex; Afifi & Bergman, 1998). The cerebellum traditionally has been relegated to motor functioning (Afifi & Bergman, 1998). However, as the cerebellum has been shown to project through the thalamus to the same cortical areas from which it receives input, including frontal, parietal, and superior temporal cortices (Lezak et al., 2004), many more deficits have been shown to derive from dysfunction of the cerebellum. In addition to reciprocal connections with the

hypothalamus and the spinal cord, the cerebellum has strong connections with the motor cortex and contributes to motor control through influences on programming and execution of actions (Lezak et al., 2004). Cerebellar dysfunction can disrupt abstract reasoning, verbal fluency, visuospatial abilities, attention, emotional modulation, planning, and time judgment.

Reductions in cerebellar volume in children with FASD have been reported extensively (Archibald et al., 2001; Mattson et al., 1996; Mattson et al., 1992; Mattson et al., 1994). Damage to the cerebellum has been implicated in learning, coordination, and balance difficulties, which have all been shown to be affected in children who have been exposed to alcohol while in utero (Wacha & Obrzut, 2007). The cerebellum is also involved in linguistic processing, word generation, set shifting, and working memory. Moreover, speed of information processing may be affected by cerebellar dysfunction (Lezak et al., 2004). The cerebellum has also been implicated as a neural system that has been incorporated in recent theoretical models of some of the impairment seen in children with ADHD (e.g., Castellanos & Tannock, 2002). A series of neuroimaging studies have reported reduced volume and activity in the cerebellum in children with ADHD (e.g., Castellanos et al., 2002; Castellanos and Tannock, 2002; Schultz et al., 2004). Castellanos and colleagues (2002) found that the cerebellum was the only region in which the volume reduction remained significant when total cerebral volume was controlled.

Many of the deficits seen in children with ADHD/FASD such as processing speed, linguistic processing, word generation, set shifting, working memory, coordination, balance, abstract reasoning, verbal fluency, visuospatial abilities, attention,

emotional modulation, planning, and time judgment may be associated with deficits in cerebellar dysfunction. It is not understood whether children with ADHD/FASD or children with ADHD will have more impairment on tasks that require intact cerebellar functioning due to the limited research comparing these two populations.

Corpus Callosum Dysfunction in Children with FASD and ADHD. The corpus callosum is a large bundle of nerve fibers connecting the two hemispheres of the brain. Interhemispheric communication maintained by the corpus callosum enforces integration of cerebral activity between the left and right hemispheres (Lezak et al., 2004). It has been suggested that FAS might be one of the leading causes of agenesis of the corpus callosum (Jeret et al., 1986). Agenesis of the corpus callosum is a congenital condition in which the callosum does not form correctly during gestation. According to Lezak and colleagues (2004), persons with agenesis of the corpus callosum tend to be generally slowed on perceptual and language tasks involving interhemispheric communication, and some show specific linguistic and visuospatial deficits. Problems with higher-order cognitive processes such as concept formation, reasoning, and problem solving with limited social insight have been observed in those with agenesis of the corpus callosum (Brown & Paul, 2000). Although agenesis of the corpus callosum is more common in individuals with FAS; most children with FASD do not have such severe alterations. However, in-depth evaluation has indicated significant changes in the size and shape of the corpus callosum in individuals with FASD (Riley & McGee, 2005), namely a reduction in size. Multiple studies have shown that those with a relatively thick callosum had patterns of EF deficits, while a thin callosum was related to motor deficits (Bookstein et al., 2002), difficulty with sensory information (Roebuck et al., 2002), and verbal

learning and memory deficits (Sowell et al., 2001). Moreover, the nature of corpus callosum abnormality in individuals with FASD has been associated with specific neuropsychological impairment (Mattson & Vaurio, 2010) such as attention, reading, learning, verbal memory, EF, and social skills deficits (Wacha & Obrzut, 2007).

The corpus callosum has also been shown to be dysfunctional in studies of children with ADHD. Hynd and colleagues (1991) examined the corpus callosum in those with ADHD and found that overall size of the callosum was reduced. This size reduction could lead to functional impairments in individuals with ADHD such as language processing and reading which both necessitate proper functioning of the corpus callosum. More recent investigations (Bush, 2009; McNally et al., 2010; Paul et al., 2007) have suggested impairment in the corpus callosum of individuals with ADHD as well. Therefore, children with ADHD and ADHD/FASD may have impairments such as motor, EF, sensory, verbal learning, memory, attention, and social skills deficits secondary to shape and overall size deficits of the corpus callosum.

Hippocampal Impairment in Children with FASD and ADHD. The hippocampus is a major component of the memory system which runs within the inside fold of each temporal lobe (Afifi & Bergman, 1998). Converging evidence from lesion studies, epilepsy surgery, and functional imaging studies points to its primary role in learning and retention (Lezak et al., 2004). Unilateral dysfunction of the hippocampus can result in lateralized processing differences while loss of the left hippocampus impairs verbal memory, and destruction of the right hippocampus results in defective recognition and recall of complex visual and auditory patterns (Lezak et al., 2004).

Evidence regarding the functioning of the hippocampus in individuals with ADHD has been mixed. Aman and colleagues (1998) found that the dysfunction related to ADHD symptomatology was not related to hippocampal impairment. Moreover, in neuroimaging studies, Perlov and colleagues (2008) found that hippocampus alteration was not stable across patients with ADHD. However, recently, Plessen and colleagues (2006) and Volkow and colleagues (2007) found hippocampal impairment to be involved in the pathophysiology of children with ADHD.

The hippocampus in those with FASD has been shown to have volume asymmetries, with the absolute volume of the hippocampus in the left temporal lobe being smaller than the corresponding region in the right temporal lobe (Wacha & Obrzut, 2007), which may lead to significant difficulties with learning and verbal memory. Furthermore, reduction in absolute hippocampal volume has been reported in some studies (Autti-Ramo et al., 2002; Bhatara et al., 2002) of children with FASD. As the hippocampus has been shown to play a major part in the memory system in humans, these findings suggest that memory impairment in individuals with FASD and individuals with ADHD may be partly due to hippocampal impairment.

Basal Ganglia Dysfunction in Children with FASD and ADHD. Within each cerebral hemisphere, at its base, are a number of nuclear masses known as the basal ganglia. According to Mattson and colleagues (2001), the basal ganglia are a group of nerve cell clusters, including the putamen, caudate nucleus, and globus pallidus, which are involved in motor abilities and EF. The basal ganglia have reciprocal connections with at least nine other cortical areas, including subdivisions of the premotor, motor, oculomotor, and prefrontal cortices (Lezak et al., 2004).

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In general, dysfunction of the basal ganglia is characterized by abnormal involuntary movements at rest (Lezak et al., 2004). Insult to the basal ganglia has been implicated in deficits in the ability to shift tasks, inhibition of inappropriate behavior, and spatial memory, which are impaired in people who have FASD (Mattson et al., 2001). Furthermore, alterations in basal ganglia circuits involved with non-motor areas of the cortex have been implicated in a wide variety of neuropsychiatric disorders including Schizophrenia, Obsessive-Compulsive Disorder, depression, Tourette's syndrome, autism, and ADHD (Lezak et al., 2004). Basal ganglia impairment has also been shown to be related to deficits in EF.

The basal ganglia appear to be especially sensitive to the effects of prenatal alcohol exposure. Even after overall brain size was controlled for, basal ganglia volume has been found to be reduced in children with FASD compared with controls (Mattson et al., 1992). More recent literature examining the basal ganglia of children with FASD using neuroimaging techniques (Archibald et al., 2001; Norman et al., 2009) has suggested impairment in these regions as well. Therefore, due to impairment in the basal ganglia in children with FASD, functional impairments in these children such as EF, motor, and memory deficits may be associated with dysfunction in the basal ganglia.

Several MRI studies reported volume reductions in the caudate nucleus of the basal ganglia in individuals with ADHD (Seidman et al., 2005). Furthermore, Filipek and colleagues (1997) found that children with ADHD had basal ganglia volume that was about 10% smaller than control children. Likewise, Castellanos and colleagues (1996) reported that the caudate nucleus and globus pallidus (both located in the basal ganglia)

of children with ADHD were approximately 10% smaller in an ADHD group over a control group.

Thalamic Dysfunction in Children with FASD and ADHD. The thalamus is a small, paired, somewhat oval structure lying along the right and left sides of the third ventricle (Lezak et al., 2004) deep inside the cerebral cortex. The thalamus is a region of great functional importance that serves as a relay center to all the main sensory systems. The thalamus should be regarded as a station where much of the information gathered from the environment is integrated and relayed to the cerebral cortex and many other subcortical regions (except the olfactory pathway; Snell, 2001). The thalamus plays a significant role in regulating higher-level brain activity (Lezak et al., 2004). The function of the thalamus is to integrate sensory and motor activities, and regulate arousal, consciousness, affective behavior, and memory (Afifi & Bergman, 1998). Neuroimaging studies have shown that right thalamic regions are involved in identifying shapes or locations and dysfunction in the right thalamic region can lead to face or pattern recognition and pattern matching difficulty (Lezak et al., 2004). Additionally, alterations in emotional capacity and responsivity tend to accompany thalamic damage, typically as apathy, loss of spontaneity and drive, and affective flattening (Lezak et al., 2004).

Multiple neuroimaging studies (e.g., Clark et al., 2000; Henry et al., 2007; Mattson et al., 1994) have shown deficiencies in the thalamus of children with FASD. Likewise, neuroimaging research by Tamm and colleagues (2006) has implicated the thalamus as being dysfunctional in children with ADHD as decreased activation was noted in this area using fMRI. Furthermore, Banich and colleagues (2009) found that attentional dysregulation in children with ADHD was purported to involve a large

number of brain regions including the thalamus. Therefore, thalamic deficiency may lead to functional impairments in children with ADHD/FASD and ADHD as the thalamus largely regulates higher-level brain activity.

Hypothalamic Dysfunction in Children with FASD and ADHD. The hypothalamus is located inferior to the thalamus just superior to the brain stem. Physiologically, there is little activity in the body that is not influenced by the hypothalamus (Snell, 2001). The hypothalamus takes up less than 0.5% of the brain's total weight; however, important behavior patterns such as rage and fear (Lezak et al., 2004), autonomic and temperature regulation, emotion, feeding, drinking and thirst, sleep and wakefulness, circadian rhythm, and memory are regulated by the hypothalamus (Afifi & Bergman, 1998). Damage to the hypothalamus can result in a variety of symptoms including obesity, disorders of temperature control, and diminished drive and responsivity. Additionally, mood states and memory may also be affected by hypothalamic dysregulation (Lezak et al., 2004).

The hypothalamus has been shown to be impacted in children with FASD in multiple studies (e.g., Gabriel et al., 1998; Hawthorne, 1992; Hellmans et al., 2007; Macri et al., 2006; Niccols 2007). Specifically the hypothalamic-pituitary-adrenal cortex (HPA) pathway has been shown to be affected (Hellemans et al., 2009; Niccols, 2007) which could lead to emotional dysregulation. The hypothalamus has also been shown to be affected in children with ADHD (Cortese & Castellenos, 2010; Hong et al., 2003; Volkow et al., 2009). These studies suggest that mood dysregulation and memory impairment may be seen in children with ADHD/FASD and ADHD due to hypothalamic impairment.

Cognitive Deficits in Children with FASD and ADHD

***Cognitive Deficits in Children with Fetal Alcohol Spectrum Disorder*.** Some of the most devastating effects of FASD are manifested in general intellectual functioning and studies in this area have been conducted extensively since the inception of the term 'FAS' in 1973 (Jones & Smith). Streissguth and colleagues (1985) found that IQ scores of individuals with FAS ranged from 20 to 86 with a mean of 61. Connor and colleagues (2000) documented low average IQ scores in adult male subjects diagnosed with FASD. According to Wacha and Obrzut (2007), individuals with FAS and FASD had mean FSIQ scores of 80 and 84 respectively. Fetal Alcohol Syndrome is thought to be the leading known cause of preventable mental retardation in the United States (Pulsifer, 1996); however, most individuals with FAS do not have mental retardation (Streissguth et al., 1996).

Given that most children with FASD do not have mental retardation, the degree of impairment in children with prenatal alcohol exposure often goes unrecognized due to the pattern of seemingly normal behavior with which these children present (Streissguth et al., 1991). The characteristics of children with FASD that are inconsistent with mental retardation may include the following: an air of alertness, appropriate affect, good superficial verbal skills, and a good sense of humor (Streissguth, 1986). These superficial characteristics can be misleading given the true level of impairment that children with FASD may actually harbor. Although the majority of children do not present with mental retardation, impairment in overall intellectual functioning has been a consistent finding in children with FASD. For instance, Mattson and Riley (1998) found that overall IQ scores

ranged from 20 to 120, with an average between 65 and 72 in children with FASD. Connor and colleagues (2000) found that children with FASD had a mean IQ of 84.

Cognitive Deficits in Children with Attention-Deficit/Hyperactivity Disorder. Compared with controls, children with ADHD typically have slightly lower full-scale IQ and subtest scores, particularly those comprising working memory (Tannock, 1998b). Psychometric testing is not required for assessment or diagnosis of ADHD, but it can provide useful standardized information about cognitive strengths and weaknesses (Quinlan, 2009). In psychological assessment, obtaining the overall IQ score is not the goal of testing, but it can be helpful to know the patient's pattern of abilities – those abilities less affected by ADHD and those abilities that are more vulnerable (Quinlan, 2009). According to Willcutt (2010), ADHD is associated with significant weaknesses on measures of inhibition, working memory, and processing speed.

As the PFC has been shown to be one of the most highly impacted areas in children with ADHD, it is understandable that functions directly assessing or required for certain tasks requiring the PFC are negatively affected. Multiple studies (e.g., Collette et al., 2005; Friedman et al., 2006; Willcutt et al., 2005) have investigated the functional impairment of children with ADHD and found that they are impaired in response inhibition, working memory, and set shifting. Other studies also found evidence for deficiencies in sustained attention, planning, organization, interference control, and fluency (Willcutt, 2010).

ADHD is a complex, neuropsychologically heterogeneous disorder, with no core neurocognitive weakness that is sufficient to explain all deficits. A multiple-deficit model has been proposed which suggests that ADHD symptoms arise from an additive and

interactive combination of multiple neuropsychological weaknesses (Willcutt, 2010). One of the most ubiquitous results in cognitive studies of ADHD is the finding that response time is slower and more variable (e.g., Castellanos & Tannock, 2002). Due to multiple areas of the brain that have been shown to be impaired in individuals with ADHD, this multiple-deficit theory appears to be substantiated.

To quantify specific areas of neuropsychological and cognitive dysfunction in children with ADHD/FASD and children with ADHD the following section will detail the composite measures of the WISC-IV along with previously reported strengths and weaknesses of children with ADHD/FASD and children with ADHD on these measures.

Wechsler Intelligence Scale for Children – Fourth Edition. The *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2000) is a measure of overall intellectual functioning that is broken down into clusters of abilities including receptive and expressive language (Verbal Comprehension Index), nonverbal reasoning (Perceptual Reasoning Index), working memory (Working Memory Index), and the ability to quickly and efficiently process information (Processing Speed Index). The WISC-IV is widely considered the gold standard in regards to measuring intellectual functioning in children and adolescents. The WISC-IV has been used in multiple studies on children with FASD to measure intellectual functioning (Davis, Boseck, Berry, Whited, & Gelder, 2009; McGee et al., 2006). The WISC-IV indexes are also useful for comparing how children function on tasks more vulnerable to impairments associated with ADHD (working memory and processing speed) compared with their baseline on cognitive functions less sensitive to impairments associated with ADHD (verbal comprehension and perceptual organization; Quinlan 2009).

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According to the special groups studies analyzing the external validity for the WISC-IV (Wechsler, 2003b), moderate effect sizes were seen for children with ADHD on the Processing Speed Index; with individual subtests showing the largest effect sizes for the Coding (Processing Speed Index) and Arithmetic (Working Memory Index) subtests. These results are consistent with research indicating that children with ADHD typically achieve low scores on measures of processing speed and working memory compared to measures of verbal or perceptual-organizational ability (Barkley et al., 2001; Pennington & Ozonoff., 1996; Wechsler, 2003b; Willcutt et al., 2001).

A second study conducted for the special groups studies (Wechsler, 2003b) analyzing 45 children with ADHD and comorbid learning disorder (LD) found that all mean composite scores for the group were significantly lower than those for the matched control group. Mean scores for the group were highest for the Verbal Comprehension Index ($\bar{x}$ =92.7, SD=15.8) and Perceptual Reasoning Index ($\bar{x}$ =92.7, SD=13.7); scores on the Working Memory Index ($\bar{x}$ =88.7, SD=13.7) and Processing Speed Index ($\bar{x}$ =88.2, SD=12.3) were lower than the VCI and PRI. However, the lowest overall score for this group was on the FSIQ ($\bar{x}$ =88.1, SD=13.0). Effect sizes for the mean composite score differences were large for the FSIQ, PSI, and WMI, and moderate for the VCI and PRI between the ADHD/LD group and the matched control group (Wechsler, 2003b).

Cognitive deficits in children with FASD have been seen to be more global and less focused as is seen in those children with ADHD (e.g., Processing Speed and Working Memory). This may be due to the widely universal neuroanatomical deficits present in children with FASD indicating that neuroanatomical dysfunction in these children is more globally extensive and severe.

***WISC-IV Subtests Used in the Proposed Analyses*.** The following diagram outlines the function of each of the subtests and the corresponding neurological areas most highly involved for each of each of the WISC-IV subtests. The function of each subtest in the middle column was taken from Sattler (2005), Wechsler (2003b), and Flanagan and colleagues (2011). The section detailing the neurological structures involved was derived from Table 1.1 (Page 34, this document) as well as Wahlstrom and Luciana (2011), Allen and colleagues (2011), Eslinger (2011), and Farmer-Dougan and colleagues (2011).

Diagram 3.1. WISC-IV Subtests, Cognitive Function, and Neurological Structures Involved in Children with ADHD and Children with ADHD/FASD.

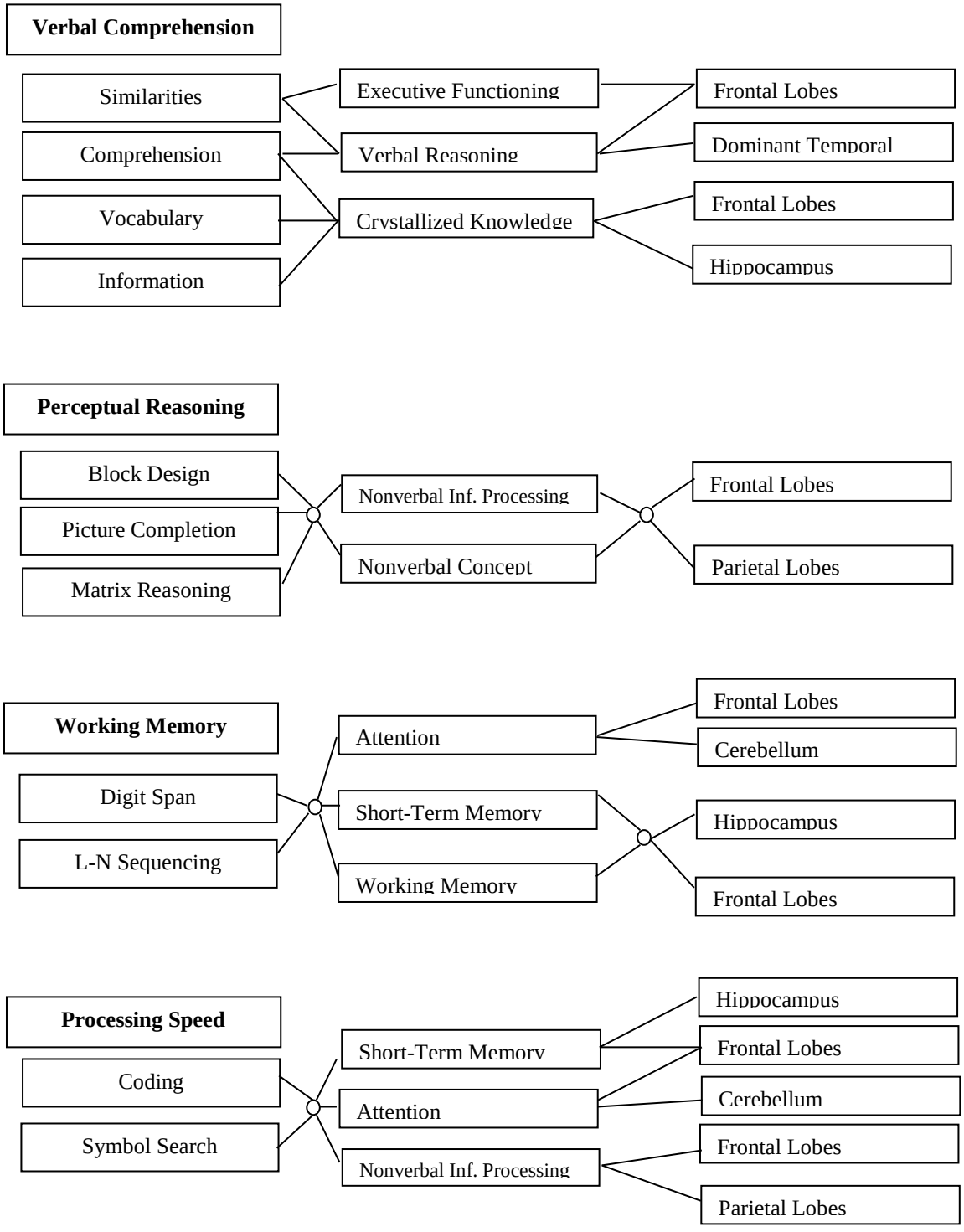


Diagram 3.1 entails a localization approach to each of the WISC-IV subtests. Recent literature has shown that there is an inherent limitation to using a localization approach considering that localization theories have largely been replaced by theories indicating that areas of the brain work in concert to produce complex behavior. Furthermore, as Mattson and Vaurio (2010) pointed out, with increasing neurobehavioral data and complementary findings, it appears that children with brain damage have domains of functional vulnerability corresponding to differential brain involvement (Mattson & Vaurio, 2010). Therefore, specific areas of the brain, although they may be more highly involved in specific cognitive abilities, must work together with other areas of the brain to produce such complex behaviors as those being investigated in this study (verbal comprehension, working memory, perceptual reasoning, and processing speed). Although specific areas of the brain do not solely account for behavior, there are certain areas of the brain that are more highly utilized than others when certain behaviors are being produced as noted in diagram 3.1.

The Verbal Comprehension Index (VCI) consists of the Similarities, Comprehension, Vocabulary, and Information subtests. According to Flanagan and colleagues (2011) the neuropsychological domains encompassed by these four subtests include Auditory-Verbal, Memory and/or Learning, Expressive and Receptive Language, and Executive Functioning (EF). Although all of these neuropsychological domains are tapped by utilizing all of the subtests in the VCI there are certain cognitive abilities that are more highly emphasized than others when examinees are completing VCI subtests (see diagram 3.1). The skills most greatly required for the VCI include EF, verbal reasoning, and crystallized knowledge.

The Similarities subtest requires verbal problem-solving ability in order to find a similitude between two verbal concepts (Sattler, 2001). As Wahlstrom and Luciana (2011) pointed out, the frontal lobes, and more specifically, the prefrontal cortex, is responsible for problem solving, planning, and decision-making which are all key components of the Similarities subtest. Comprehension is a subtest on the VCI that requires verbal reasoning and crystallized knowledge in order for the examinee to answer questions gauging their understanding of fundamental behavior and social situations (Sattler, 2001). Examinees must use verbal reasoning to guide themselves through the situations based on their understanding of language-based human behavior. Comprehension also requires crystallized knowledge as having a firm understanding of the linguistic concepts involved in the questions on this subtest is required to answer correctly. The dominant temporal lobe (usually the left temporal lobe) is utilized in verbal reasoning concepts as the temporal lobes are active in processing auditory input and in long-term storage of sensory input (memory; Kolb and Whishaw, 2009).

The frontal lobes are active in verbal reasoning concepts as the frontal lobes are engaged in tasks that require language and EF such as reasoning through verbal concepts that require understanding, choice, and selection. Crystallized knowledge is required during the Comprehension subtest as well and crystallized knowledge, or memory for language, is largely accounted for by the hippocampus as this area of the brain figures prominently in memory (Kolb and Whishaw, 2009). The frontal lobes are also engaged in discussions of crystallized knowledge as the frontal lobes are utilized when selecting behaviors on the basis of internalized knowledge (Kolb and Whishaw, 2009).

The Perceptual Reasoning Index (PRI) consists of Block Design, Picture Concepts, and Matrix Reasoning. Flanagan and colleagues (2011) indicated that these subtests require the following neuropsychological domains: Visual-Spatial and Detail, EF, and Memory and/or Learning. Nonverbal information processing and concept formation are required for all of these subtests as the primary purpose of the PRI is to assess the examinee's ability to analyze and synthesize nonverbal information. The frontal lobes are used during PRI tasks as the frontal lobes are highly engaged during problem-solving, planning, and decision-making (Wahlstrom and Luciana, 2011). The parietal lobes are also an area of primary activation during PRI tasks as the function of the parietal lobes includes spatial and nonspatial working memory, calculation, and modulation of visual attention (Wahlstrom and Luciana, 2011).

The Working Memory Index (WMI) includes the Digit Span and Letter-Number Sequencing subtests. These subtests, according to Flanagan and colleagues (2011) require the following neuropsychological domains: Attention, Auditory-Verbal, Memory and/or Learning, and EF. Attention is highly utilized during these tasks as the examinee must attend to and focus on the tasks in order to correctly store and express the information back to the examiner. The frontal lobes are an essential cortical area for attentional capacity as attention is one of the primary EFs (Miller, 2007) and is an essential area of activity during focused attention, shifting attention, and metacognition (Rizzo and Kellison, 2010). The cerebellum is also an essential neuroanatomical area utilized during the complex activity of attention. According to Allen and colleagues (2011), one of the primary impairments in individuals with cerebellar lesions is attention. Furthermore,

according to Lezak and colleagues (2004) cerebellar damage has been shown to disrupt attentional capacity.

Short-term memory, the ability to store rote information for a short period of time, utilized during WMI tasks, requires hippocampal and frontal lobe functioning as both of these areas of the brain are used during storage of verbal and nonverbal information (i.e., Kolb and Whishaw, 2009; Lezak et al., 2004). Working memory, a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex tasks as comprehension, learning, and reasoning (Baddeley, 2000), is utilized during WMI tasks and is also largely accounted for by the frontal lobes and hippocampus as these areas of the brain are highly responsible for working memory activity (i.e., Eslinger, 2011; Lezak et al., 2004).

The Processing Speed Index (PSI) consists of the Coding and Symbol Search subtests. According to Flanagan and colleagues (2011) Coding and Symbol Search require Speed and Efficiency, Attention, Visual-Spatial and Detail, Memory and/or Learning, and EF abilities. The most highly utilized abilities during Coding and Symbol Search include short-term memory, attention, and nonverbal information processing. Short-term memory is required during PSI tasks as the temporary storage of symbols and numbers is necessary in order to successfully complete the tasks. The hippocampus and frontal lobes are utilized during short-term memory tasks (i.e., Eslinger, 2011; Lezak et al., 2004). Attention is also critical during PSI tasks as the examinee must attend and focus for an extended period of time in order to successfully complete the tasks. The frontal lobes and cerebellum are critical during tasks of attention (i.e., Allen et al., 2011; Lezak et al., 2004). Nonverbal information processing is also critical during PSI tasks as

examinees must analyze nonverbal information in order to navigate through the tasks. The frontal lobes and parietal lobes are both highly emphasized during tasks requiring nonverbal information processing (i.e., Wahlstrom and Luciana, 2011).

Verbal Comprehension Deficits in Children with ADHD and FASD. Children with ADHD and FASD have been shown to have deficits in receptive and expressive language. Gross-Tsur and colleagues (1991) found that the onset of language (as assessed by the appearance of first words and short sentences) may be delayed in children with ADHD. Furthermore, receptive and expressive language ability deficits have been reported in children with ADHD, with expressive language being particularly impaired (Oram et al., 1999; Tannock & Brown, 2000). Moreover, many children with ADHD referred solely for disruptive behavior disorders have moderate to severe language impairments that have not been recognized previously and are identified only on systematic assessment (Tannock & Brown, 2000).

Language impairment may be due to many areas of the brain that have been shown to be impacted in children with ADHD and FASD. In children with ADHD, the frontal lobes may contribute to language impairment as the frontal lobes largely orchestrate behavior and are also the area most highly responsible for expressive language. Barkley (1997; 2006) and Willcutt (2010) found that children with ADHD had impaired frontal lobe functioning. Impaired frontal lobe functioning may affect language development and language expression. Furthermore, Castellanos & Tannock (2002) found cerebellar dysfunction in children with ADHD. This impairment may contribute to difficulty with the motor aspects of language. The temporal lobes have also been shown to be impaired in children with ADHD (Kobel et al., 2010; Rubia et al., 2007). Finally,

the corpus callosum was shown to be impaired in children with ADHD (Bush, 2009; Hynd et al., 1991; McNally et al., 2010; Paul et al., 2007) which has been shown to be pivotal in relaying spatial and linguistic information between the hemispheres. Although all of these areas may deleteriously affect the language functioning of children with ADHD, far more areas of the brain in children with FASD associated with language are impaired (e.g., frontal lobe, temporal lobe, parietal lobe, corpus callosum, cerebellum, hippocampus, and hypothalamus).

Children with FASD have been shown to have impairment in the left frontal lobe (Archibald et al., 2001; Sowell et al., 2001), temporal lobe (Sowell et al., 2001), parietal lobe (Riikonen et al., 1999), cerebellum, (Mattson et al., 1996, Archibald et al., 2001, Mattson et al., 1992, Mattson et al., 1994), corpus callosum, (Riley & McGee, 2005), hippocampus (Wacha & Obrzut, 2007), and hypothalamus (Gabriel et al., 1998; Druse, 1992; Hawthorne, 1992). These areas of neuroanatomical dysfunction may impair language in children with FASD. Damage to the corpus callosum has been linked to deficits in verbal memory and EF (Wacha & Obrzut, 2007). The hippocampus in individuals with FASD has been shown to have volume asymmetries, with the absolute volume of the hippocampus in the left temporal lobe being smaller than the corresponding region in the right temporal lobe (Wacha & Obrzut, 2007) which may result in poor verbal memory. Finally, damage to the cerebellum can disrupt abstract reasoning, word generation, and verbal fluency.

Perceptual Reasoning Deficits in Children with ADHD and FASD. Research on perceptual abilities is varied in children with ADHD. According to Rubia and colleagues (2007), fMRI was used to show reduced brain activation in right superior temporal lobes

in children with ADHD which was hypothesized to lead to dysfunction in perceptual attention response variability. However, according to Barkley (2006), research on visual-spatial working memory in ADHD is rather limited, characterized by a diversity of tasks believed to evaluate this working memory construct, and according to Barkley (2006), for the moment, it must be concluded that such a deficit does not exist. Furthermore, according to Wechsler (2003b), children with ADHD perform in the normative range of functioning on measures of perceptual-organizational ability. Due to discriminating research, perceptual reasoning abilities in children with ADHD must be further researched in order to exemplify possible implications.

Multiple studies have shown that children with FASD have impairment in visual-spatial functioning. Kerns and colleagues (1997) found that children with FASD had low visual-spatial functioning using the *Wechsler Intelligence Scale for Children – Revised* (Wechsler, 1974). Additionally, Kaemingk and colleagues (2003) found that children with FASD had significant problems with immediate visual learning on the *Wide Range Assessment of Memory and Learning Tests* (Adams & Sheslow, 1990).

Visual-spatial functioning has largely been considered a right hemisphere process whereas the left hemisphere has been widely implicated in language processing. Additionally, the parietal lobe of the right hemisphere is largely considered a visual-spatial processing center. According to neuroanatomical research on children with ADHD, the parietal lobes have been found to be dysfunctional (Cherkasova & Hechtman, 2009; Rubia et al., 2008; Wang et al., 2007). The parietal lobes have also been found to be impaired in children with FASD (e.g., Sowell et al., 2001). Therefore, although research has not shown significant deficits in visual-spatial processing for children with

ADHD, these deficits in visual-spatial processing may be found in children with ADHD as well as children with ADHD/FASD due to neuroanatomical deficits in each of these populations.

Working Memory Deficits in Children with ADHD and FASD. Memory is frequently affected in children with ADHD. Often, long-term memory is intact, but working memory is impaired (Quinlan, 2009). This may be secondary to the fact that memory requires attention, and in order to remember information one must first attend to that information.

One of the theories regarding these memory deficits in children with ADHD is a neurochemical theory. Solanto (2001) indicated that dopamine imbalances in the PFC of children with ADHD can impair working memory; furthermore, the PFC is extremely sensitive to stress (overstimulation) and under-stimulation, which can both lead to working memory deficits secondary to dopamine imbalances. Hippocampal impairment has also recently been implicated in the deficits of children with ADHD (e.g., Plessen et al., 2006; Volkow et al., 2007). These hippocampal deficits may lead to memory impairment in individuals with ADHD. Other cortical areas that have been shown to be impaired in individuals with ADHD which may lead to memory impairment include the hypothalamus (Cortese et al., 2008; Hong et al., 2003; Volkow et al., 2009), basal ganglia (Castellanos et al., 1996; Filipek et al., 1997; Lezak et al., 2004; Seidman et al., 2005), cerebellum (Castellanos et al., 2002; Castellanos and Tannock, 2002; Schultz et al., 2004), and thalamus (Banich et al., 2009; Tamm et al., 2006).

Numerous studies have found scores for Digit Span, a selective attention and working memory task, to be significantly lower than those for other verbal subtests in

individuals with ADHD (Quinlan, 2009). Quinlan (2009) found that children with ADHD had scores on the Digit Span subtest that were 1.4 standard deviations below the mean of the Verbal Index. Furthermore, a recent meta-analysis (Frazier et al., 2004) involving 12 studies using the Digit Span subtest reported a significant weighted mean effect size of 0.64 (95% CI = 0.52-0.76), indicating moderate deficits in children with ADHD in the working memory domain.

Multiple studies have specifically investigated working memory in children with FASD. All studies investigating working memory in children with FASD have shown substantial deficits (e.g., Kodituwakku et al., 1995; O'Hare et al., 2005; Rasmussen, 2005). It was also suggested that deficits in working memory are perhaps the primary mechanism of cognitive deficits in children with FASD (O'Hare et al., 2005). Working memory has largely been thought to be one of the cognitive tasks most highly reminiscent of EF as working memory tasks involve processing, manipulating, regulating attention, analyzing, synthesizing, and producing information. Executive functioning tasks are largely regulated by the frontal lobes, and more specifically the PFC, which has been shown to be impaired in children with both ADHD and children with FASD. Working memory has also been shown in neuropsychological and neuroimaging studies to involve the cerebellar regions and cerebellum which have both been shown to be affected in children with ADHD and children with FASD.

Beyond the PFC, working memory functions may be more impaired in individuals with FASD as the temporal lobes (Vaurio et al., 2008b), hippocampus (Autti-Ramo et al., 2000; Bhatara et al., 2002), basal ganglia (Mattson et al., 1992), thalamus (Henry et al., 2007; Mattson et al., 1994), and hypothalamus (Gabriel et al., 1998; Druse, 1992;

Hawthorne, 1992) have all been shown to be deleteriously affected in this population. All of these areas of the brain serve a memory function. Furthermore, of these neuroanatomical regions of the brain, only the basal ganglia was shown to be deleteriously affected in individuals with ADHD (Filipek et al., 1997). The hippocampus, thalamus, and hypothalamus were all shown to be spared in individuals with ADHD. Therefore, it is suspected that working memory will be impaired in children with ADHD as well as children with ADHD/FASD. However, working memory is suspected to be more impaired in individuals with ADHD/FASD.

Processing Speed Deficits in Children with ADHD and FASD. Theoretical models of ADHD do not posit processing speed as a single core weakness that is necessary and sufficient to cause ADHD, and neural models of processing speed are less advanced than models of executive control processes and delay aversion (inhibition; Willcutt, 2010). However, processing speed has been shown to be sensitive to neurological conditions such as ADHD (Donders, 1997).

Recent evidence on groups with ADHD has shown large and consistent deficits on measures of cognitive processing speed (e.g., Willcutt, 2010). Furthermore, Lawrence and colleagues (2004) found deficits in processing speed in children with ADHD on neuropsychological measures including a Stroop task and the *Wisconsin Card Sorting Test* (WCST; Heaton et al., 1993). Neuroanatomically, areas that have been shown to be impaired in individuals with ADHD that may be contribute to processing speed deficits include the basal ganglia (Castellanos et al., 1996; Filipek et al., 1997; Lezak et al., 2004; Seidman et al., 2005), cerebellum (Castellanos et al., 2002; Castellanos and Tannock, 2002; Schultz et al., 2004), corpus callosum (Bush, 2009; Hill et al., 2003; Hynd et al,

1991; McNally, 2010; Paul et al., 2007), frontal lobe (Barkley, 1997; 2006; Carey, 1998; Hill et al., 2003; Seidman et al., 2005; Solanto et al., 2005; Willcutt, 2010), hippocampus (e.g., Plessen et al., 2006; Volkow et al., 2007). parietal lobe (Aman et al., 1998; Cherkasova & Hechtman, 2009; Wang et al., 2007), and thalamus (Banich et al., 2009; Tamm et al., 2006).

Kulaga (2006) specifically investigated processing speed in children with FASD using the Sternberg paradigm from the original *Sternberg Memory Scanning Task* (Sternberg, 1966) Memory Rotation Test, Number Comparison Test, and Arrow Discrimination Test. Kulaga found a significant correlation between prenatal alcohol exposure and processing speed. Further studies (Carmichael-Olson et al, 1998; Rasmussen, 2005) have also found significant deficits in processing speed for children with FASD.

The frontal lobes have been shown to play an executive role in regulating and carrying out behavior. Therefore, the dysfunction seen in the frontal lobes of children with FASD may impact processing speed. Furthermore, children with FASD have been shown to have impairment in the cerebellum (Mattson et al., 1996, Archibald et al., 2001, Mattson et al., 1992, Mattson et al., 1994), corpus callosum (Riley & McGee, 2005), thalamus (Henry et al., 2007; Mattson et al., 1994), and hypothalamus (Gabriel et al., 1998; Druse, 1992; Hawthorne, 1992), which all directly or indirectly affect processing speed. Due to the extensive neuroanatomical dysfunction seen in both children with ADHD and children with FASD, it is postulated that processing speed may be impacted in individuals in both of these populations.

Adaptive Skill Deficits in Children with FASD and ADHD. Although cognitive skills are important in assessing general functional level, they should be used in conjunction with tests of functional and adaptive skills in evaluating developmental disability in individual patients (Streissguth & Randels, 1989). Adaptive functioning refers to an individual's ability to meet developmentally appropriate expectations of personal independence and social responsibility (Sparrow, Balla, & Cicchetti, 1984) and includes the ability to perform everyday tasks and adapt to changes in the environment (Crocker et al., 2009). Deficits in adaptive functioning can hamper an individual's ability to navigate in many areas of life. Management of everyday stressors and completion of basic tasks necessary for daily living are dependent on intact adaptive functioning (Crocker et al., 2009). Evidence exists that adaptive functioning impairments that persist into adulthood can result in adverse life outcomes such as disrupted school experiences, trouble with the law, and substance abuse problems (Streissguth et al., 2004).

Children with FASD may have deficits in physical, behavioral, emotional, and/or social functioning as a result of prenatal alcohol exposure (Streissguth & O'Malley, 2000). Adaptive ability in children with FASD is characterized by an arrest in development, as evidenced by a lack of improvement in socialization and communication as these children age; in contrast, children with ADHD exhibit a developmental delay in adaptive ability as their adaptive ability continues to improve with age (Crocker et al., 2009). Therefore, it is suspected that children with ADHD will continue to improve their adaptive functioning, whereas children with ADHD/FASD may reach a limit and not be able to improve these adaptive skills past a certain age.

Children exposed to alcohol prenatally show an array of deficits in adaptive functioning that persist throughout the lifespan (Whaley et al., 2001). In studies of adolescents and adults with FASD, clear deficits in adaptive functioning have been documented (LaDue et al., 1992; Streissguth et al., 1991). Streissguth and Randels (1989) described adaptive functioning concerns that grew more prevalent with age in children with FASD. These adaptive concerns may be secondary to the cognitive deficits prevalent in children with FASD.

When compared to typically developing individuals with approximately the same level of general intelligence, individuals with ADHD obtain lower standard scores in all domains of adaptive functioning (Sparrow, Cicchetti, & Balla, 2005). Additionally, it is common for children with ADHD to be more delayed than their typically developing peers in the habitual or routine execution of daily living activities (Sparrow, Cicchetti, & Balla, 2005).

Vineland Adaptive Behavior Scales. The *Vineland Adaptive Behavior Scales* (VABS; Sparrow, Balla, & Cicchetti, 1984) are a widely used measure of adaptive functioning in newborn children to adults. The VABS measures communication, daily living skills, socialization, and motor skills. Research has shown that the reliability and validity indexes of the VABS are high.

Communication Deficits in Children with ADHD and FASD.

Communication Domain. Children with ADHD in the VABS clinical validity study were shown to have lower scores on the Receptive Communication domain than a nonclinical reference group (Sparrow, Balla, & Cicchetti, 1984). It is expected that the individuals with ADHD in this study by Sparrow and colleagues (1984) had difficulty

maintaining focus and attention needed for effective performance in communication (e.g., listening attentively; Sparrow, Cicchetti, & Balla, 2005). Children with ADHD in the VABS validity study also showed poor performance on the Expressive domain compared to a nonclinical reference group. This deficit may have been due to difficulty staying on the topic of conversation and being impulsive during conversation. Also, children in the VABS validity studies who had ADHD performed lower on the Written Domain than did nonclinical control groups.

Multiple studies have found that children with FASD struggle with communication. These communication deficits are likely due to many of the deficits seen in verbal comprehension as was shown previously on the WISC-IV. Furthermore, specifically, Wacha and Obrzut (2007) found that adolescents with FASD frequently displayed poor communication skills. Neuroanatomical impairment associated with communication deficits such as frontal lobe and left hemisphere dysfunction are likely to have an impact on language. Deficits in EF, verbal memory, and language acquisition and maintenance will all highly impact a child's ability to communicate effectively. Specific areas of the brain that are likely to lead to communication deficits include the frontal lobes (EF, verbal memory), corpus callosum (EF, verbal memory, general slowing on language tasks), hippocampus (verbal memory), cerebellum (abstract reasoning, word generation, verbal fluency), and thalamus (language acquisition and maintenance). All of these areas are affected in children with FASD and ADHD. Therefore, it is speculated that children with ADHD/FASD and children with ADHD may have significant communication skills deficits.

Daily Living Skills Deficits in Children with ADHD and FASD.

Daily Living Skills Domain. The *Behavior Rating Inventory of Executive Functioning* (BRIEF; Gioia et al., 2000) is a measure of metacognitive, behavioral, and emotional abilities that go beyond common psychopathology and behavioral disturbances (Rasmussen et al., 2007). Rasmussen and colleagues (2007) measured these skills in children with FASD and found that children with FASD struggled on all measures of the BRIEF suggesting particular difficulty on initiation of tasks, and generating ideas, responses, and problem-solving strategies. More specifically, Coles and colleagues (1991) as well as Thomas and colleagues (1998) used the VABS to examine adaptive behavior in children with FASD and found particular deficits in daily living skills.

Conversely, Sparrow and colleagues (2005) did not find significant differences in Daily Living Skills on the *Vineland Adaptive Behavior Scales – II* (VABS-II; Sparrow, Cicchetti, & Balla, 2005) between children with ADHD and a non-clinical sample. However, Barkley (2006) concluded that skills such as dressing, bathing, feeding, toileting requirements, as well as using and telling time are some of the adaptive skills that may be so substantially impaired in individuals with ADHD that these deficits may be a hallmark of the diagnosis. Due to the discrepancy between the opinions of Barkley (2006) and Sparrow and colleagues (2005), future research may need to be conducted concerning daily living skills for children with ADHD in order to account for possible impairment in these skills.

Daily living skills generally require intact EF skills such as working memory, attention, organization, and inhibition which have all been shown to be deficient in children with both ADHD and children with FASD. Therefore, daily living skills deficits

seen in these populations may be due to EF deficits secondary to dysfunction in the frontal lobes and, more specifically, the PFC. Daily living skills also require memory; therefore, children with FASD and children with ADHD may have impairment in these abilities secondary to temporal lobe, hippocampus, basal ganglia, thalamus, and hypothalamus dysfunction which all show involvement in memory functioning. Therefore, daily living skills deficits may be prominent in children with ADHD/FASD and children with ADHD.

Socialization Deficits in Children with ADHD and FASD.

*Socialization Domain***.** Children with ADHD have been shown to have deficits in all areas of social functioning. Perhaps the most devastating impact of ADHD is reflected in the strong tendency for children with this disorder to be rejected by their peers (Hinshaw, 1998). Children in the VABS-II validity studies with ADHD had low scores in Interpersonal Relationships (Sparrow, Cicchetti, & Balla, 2005). These social skills deficits may be secondary to ADHD symptomatology such as impulsivity, hyperactivity, and inattentiveness that is seen in this population.

Evidence points to the specific difficulties experienced by children with ADHD in making and keeping friends (Hinshaw, 1998). These social difficulties do not appear to be related specifically to deficits in social knowledge or social skill; rather, children with ADHD have marked problems with the performance of appropriate social behavior (Hinshaw, 1998; Whalen & Henker, 1992). The peer rejection of youth with ADHD is clinically and prognostically of the utmost importance (Hinshaw, 1998). Especially given that, (a) peer rejection in childhood is a robust predictor of negative long-term outcomes such as school dropout, delinquency, and adult mental health problems (Parker & Asher,

1987) and that, (b) such predictions hold even when initial levels of problem behavior are controlled (Greene et al., 1997; Hinshaw, 1998). Diamond (2006) hypothesized that many social skills deficits seen in children with ADHD are due to these children being too assertive, taking things that belong to others, failing to wait their turn, and acting without considering the feelings of others.

Children with ADHD in the VABS-II validity studies were shown to have lower scores on the Coping Skills domain which may be secondary to struggles with impulsivity. Subjects in this study struggled with tasks such as not interrupting when others were talking (Sparrow, Cicchetti, & Balla, 2005); which may have been secondary to impulsivity. Furthermore, children in the VABS validity studies with ADHD had low scores in Play and Leisure Time, possibly due to difficulty with events such as taking turns during social activities (Sparrow, Cicchetti, & Balla, 2005).

Similarly, socialization may be particularly affected in individuals with prenatal alcohol exposure (Crocker et al., 2009). Social problem-solving is important to study because of its wide-ranging impact on adaptive functioning (McGee et al., 2008). Social problem solving involves efficient use of many of the components of EF including that individuals must: be able to identify a problem, use past and current information to generate and develop potential solutions, and choose and implement the most effective solution while inhibiting less effective responses and monitoring the effect the solution has on other individuals (D'Zurilla et al., 1999). All of these skills are likely to be impaired in individuals with FASD as it has been shown that their EF is poor in comparison with same-aged peers.

The socialization deficits associated with FASD include poor interpersonal skills, difficulty understanding social cues, inappropriate social behavior, difficulty communicating in social contexts, and an inability to conform to social conventions (Streissguth, 1997). These social skills deficits in children with FASD may be attributed to EF deficits, suggesting that individuals with EF deficits have poor social problem-solving skills (McGee et al., 2008).

Analyses conducted by Davis, Boseck, Berry, Whited, and Gelder (2009) with 40 children diagnosed with FASD indicated significant correlations between the WISC-IV Indexes and VABS Composite scores. In this study, FSIQ was able to predict a substantial proportion of the variance in the Communication, Daily Living, and Adaptive Behavior Composite, but not the Socialization Composite. These results suggest that social skill problems are likely pervasive among this population regardless of intellectual functioning and should be a primary avenue of intervention, while the other adaptive skills seem more dependent upon cognitive ability (Davis et al., 2009). These findings also suggest that social skills deficits may be a function of EF deficits, as cognitive deficits (besides working memory, which is an EF) did not account for a significant amount of the variance in the VABS composites.

Additionally, two studies have documented relatively greater impairment on the Socialization domain (Streissguth et al., 1991; Thomas et al., 1998) of the VABS, even when Verbal IQ was controlled (Thomas et al., 1998) in children with FASD. It has been suggested that EF deficits play a role in social skills deficits seen in children with FASD. Parent-reported deficits in social skills as measured by the Social Skills Rating System have been shown to be significantly correlated with parent-reported EF deficits,

suggesting that higher-order cognitive deficits may contribute to interpersonal difficulty (Schonfeld, et al., 2006).

Given all of this evidence of socialization skills deficits seen in children with ADHD and FASD and the conclusion that many of these deficits may be due to EF dysfunction, it is suggested that socialization skills deficits may be secondary to those areas of the brain responsible for EF such as the frontal lobes and more specifically, PFC, which have been shown to be impaired in both of these populations. Therefore, social skills are postulated to be impaired in children with ADHD/FASD as well as children with ADHD.

Motor Skills Deficits in Children with ADHD and FASD.

Motor Skills Domain. It is well known that ADHD is often comorbid with psychiatric disorders such as mood and anxiety disorders, illicit drug use, antisocial behavior, tics, and learning disorders; however, it is often less well known that ADHD is also highly associated with motor control dysfunction, clumsiness, and Developmental Coordination Disorder (DCD; APA, 2000; Gillberg & Kadesjo, 2009). Gillberg and Kadesjo (2009) found that ADHD is associated with DCD in about half of all cases. Therefore, clinicians working with patients with ADHD need to be aware of the very strong association with motor impairment and should be able to diagnose motor control problems (Gillberg & Kadesjo, 2009). Because of the documented strong associations between ADHD and motor control problems in research and clinical practice, and because of the difficulty in determining which domain (attention or motor-perceptual) should be regarded as primary, the concept of "Deficits in Attention, Motor control, and Perception," or DAMP, was launched in the Nordic countries in the early 1980s (Gillberg

et al., 1982; Gillberg & Kadesjo, 2009). These studies suggested that attention, motor control, and perception are all impaired in children with ADHD and should be an area of primary concern for clinicians working with children with ADHD.

Likewise, along with children with ADHD, those children with FASD have been shown to have significant motor skills impairment in both fine and gross motor tasks (Wacha & Obrzut, 2007). O'Leary (2004) found that children with FASD may have fine and gross motor skills deficits by as early as 12 months of age. Furthermore, Jacobson and colleagues (1994) investigated these deficits and found that children with FASD had abnormal walking, balance, and fine motor coordination deficiencies that were present at approximately one year of age.

Neuroanatomically, the cerebellum has long been suggested to play a major role in motor skills. The cerebellum has been shown to be impaired in children with ADHD and children with FASD; therefore, the level of impairment in these populations in motor skills may be partly attributable to their cerebellar dysfunction. However, complex functions such as motor control require most of the cerebral cortex as the brain has been shown to work in concert to produce behavior. Furthermore, the basal ganglia has been suggested to play a major role in most motor functions as the basal ganglia is a significant contributor in the motor system. Therefore, dysfunction in the cerebellum as well as the basal ganglia in individuals with ADHD and individuals with FASD may be the main contributing factors to deficits in motor functioning.

Conclusions

The investigation of the effects of intrauterine alcohol exposure continues to be an important area of study in psychology. Neuroanatomical, neuropsychological, cognitive,

adaptive, and behavioral deficits in this population continue to be quantified in empirical research. Investigating the neuroanatomical, neuropsychological, cognitive, adaptive, and behavioral skills deficits in children with ADHD/FASD and children with ADHD leads to the hypothesis that these two disorders present with similar patterns of dysfunction. However, a thorough investigation linking similarities and differences between those with comorbid ADHD/FASD and ADHD has not yet been conducted. A methodical investigation between children with ADHD/FASD and children with ADHD is expected to yield several findings. First, those with ADHD/FASD may be recognized at an earlier age, thus advancing specifically-catered interventions for the ADHD/FASD population. Second, psychopharmacological treatment for those with ADHD/FASD may be improved. Finally, investigating the strengths and weaknesses of those with ADHD/FASD may help psychologists work with these children in the home and school environments. School systems often request that school psychologists take the lead in developing appropriate interventions and accommodations for children with neurodevelopmental disorders (Davis & Phelps, 2008); hence, an increased understanding of these disorders (e.g., FASD) is essential. School psychologists, to serve as effective advocates for children, should focus on outcomes, employ more preventative techniques, utilize empirically supported interventions, and take an active role in initiating changes in their schools and the communities (Davis, 2001).

Chapter 3

Methodology

This chapter is organized into four sections: (1) Participant Selection; (2) Procedures, (3) Instrumentation, Validity, and Reliability; and (4) Statistical Procedures and Data Analysis. The purpose of this chapter is to provide a detailed explanation of how the participants were selected and what procedures were undertaken to collect and analyze the data.

Participant Selection. This study compared children with comorbid ADHD/FASD and children with ADHD to quantify the cognitive and adaptive skills deficits present in these two groups, differentiate the cognitive and adaptive abilities in both groups, and identify the best predictors of group membership for the ADHD/FASD and ADHD groups based on adaptive and cognitive abilities. Due to the highly important construct of gender that is present in children with each of these disorders, children with ADHD and children with ADHD/FASD were compared in this analysis depending on their gender. Therefore, there were four groups being analyzed in this study, (1) male children with ADHD, (2) female children with ADHD, (3) male children with ADHD/FASD, and (4) female children with ADHD/FASD. The effects of prescription medication and race were also analyzed to determine if these factors played a part in

differentiating the diagnostic groups through the use of MANOVA using ethnicity and stimulant medication as independent variables. The first MANOVA analyzing the individual subtests of the WISC-IV indicated that there was an insignificant overall omnibus value for ethnicity [F (1, 227) = 1.40; p > .05; Table 3.1.] and stimulant medication [F (1, 227) = 0.93; p > .05; Table 3.2.].

Table 3.1.

Ethnicity as an Independent Variable

	Ethnicity	
Subtest	MS	F (1,227)
Block Design	10.22	1.13
Similarities	8.98	1.73
Digit Span	5.75	0.76
Picture Concepts	94.04	7.28**
Coding	17.41	1.74
Vocabulary	10.32	1.90
L-N Sequencing	22.71	0.93
Matrix Reasoning	5.79	0.63
Comprehension	15.55	2.63
Symbol Search	5.03	0.24
Information	26.60	4.17*

Table 3.2.

Prescription Medication as an Independent Variable

	Prescription Medication	
Subtest	MS	F (1,227)
Block Design	4.42	0.55
Similarities	0.03	0.01
Digit Span	3.60	0.49
Picture Concepts	7.48	0.75
Coding	0.55	0.06
Vocabulary	1.51	0.31
L-N Sequencing	31.80	3.19
Matrix Reasoning	0.36	0.41
Comprehension	0.28	0.05
Symbol Search	4.86	0.70
Information	6.85	1.15

According to these analyses, neither of these variables statistically differentiated between groups in regards to their cognitive ability or adaptive skills and were therefore left out of the final analyses.

Most of the children in this sample were also diagnosed with comorbid conditions. It is not uncommon for children with ADHD/FASD or ADHD to be diagnosed with other conditions. As such, the analysis was run without consideration of these secondary conditions but the possibility remains that comorbid conditions may have

affected the results and this will be addressed in the discussion section. The following table expresses the comorbid conditions of each of these samples:

Table 3.3

Comorbid Conditions

	ADHD (N=147)	ADHD/FASD (N=81)
Organic Encephalopathy	42 (28.6%)	62 (76.5%)
Depression	101 (68.7%)	41 (50.6%)
Anxiety	117 (79.6%)	50 (61.7%)
PTSD	22 (14.9%)	16 (19.8%)

All patients in this study were administered the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003) and *Vineland Adaptive Behavior Scales* (Sparrow, Balla, & Cicchetti, 1984). Children diagnosed with mental retardation were excluded from this study. All information from participants in this study was gathered from an archival database collected by a clinical neuropsychologist. This neuropsychologist worked as part of a diagnostic team including a physician specializing in medical genetics and pediatrics to make diagnoses of FASD. According to the neuropsychologist, referrals sources included the following; medical geneticists, pediatric neurologists, pediatricians, court orders, Department of Children's Services, residential treatment facilities, foster care facilities and homes, and caregivers (personal communication, January, 2010).

All patients diagnosed with ADHD were identified as having Attention-Deficit/Hyperactivity Disorder, Combined Type. This diagnosis was based upon observation, interview, psychological assessment procedures, parent/caregiver rating forms, as well as teacher rating forms when available. A diagnosis of ADHD, Combined

ADHD WITH OR WITHOUT COMORBID FASD

Type was given when patients met DSM-IV-TR criteria for this condition. According to the assessing neuropsychologist, all patients prescribed stimulant medication were directed to take their medication the morning upon being evaluated (Gelder, personal communication, August 11, 2010).

All patients diagnosed with FASD were jointly examined by both the neuropsychologist and physician. According to the physician (Bader, personal communication, January 13, 2010), all children who were diagnosed with FASD were classified as such based upon The 4-Digit Diagnostic Code outlined at the FAS Diagnostic and Prevention Network at a conference presentation conducted at the University of Washington (Astley & Clarren, 1999). The four criteria include:

1. Positive history of prenatal alcohol exposure. Direct confirmation of a history of prenatal alcohol exposure was used when available. The physician explained (Personal Communication, January 13, 2010) that many times inferential information such as a history of the biological mother having been arrested for alcohol-related offenses or rehabilitation for alcohol use was used to meet this criteria when direct confirmation of a history of prenatal alcohol exposure was unavailable.
2. Pre and/or postnatal growth deficiency (e.g., small for gestational age, low birth weight, low weight to height ratio, short stature).
3. Central nervous system dysfunction. This could include behavioral (e.g., hyperactivity, inattention, social skills deficits), cognitive (e.g., IQ deficits, memory deficits), or adaptive (e.g., developmental delay in skills of daily living) skills dysfunction. The neuropsychologist joined in the team evaluation

procedures at this point to assess these particular deficits through valid and reliable psychological assessment procedures.

4. Physiological dysmorphology. The physician stringently examined craniofacial anomalies in each patient. Craniofacial anomalies that were examined included; microcephaly, epicanthal folds, flat midface, smooth or flattened philtrum, underdeveloped jaw, low nasal bridge, small eye openings, short nose, and thin upper lip.

For the purposes of this study, those children included under the diagnostic classification of ADHD/FASD must have met the first criteria of positive prenatal alcohol exposure plus at least one of the other three criteria. Therefore, those children diagnosed with 'Fetal Alcohol Syndrome' (those children who met all four criteria), 'Fetal Alcohol Spectrum Disorder' (children who met the first criteria plus any one of the other three criteria), 'Fetal Alcohol Effects' (a term previously used to describe children with FASD who did not have extensive symptomatology), and 'Alcohol-Related Neurodevelopmental Disorder' (another term previously used to describe children with a positive history of intrauterine alcohol exposure plus developmental delay) with comorbid ADHD were used in this study as the ADHD/FASD diagnostic group.

Procedures. All participants in this study were administered a comprehensive neuropsychological battery by a Ph.D. level clinical neuropsychologist consisting of the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003) and the *Vineland Adaptive Behavior Scales* (Sparrow, Balla, & Cicchetti, 1984) among other neuropsychological measures using a flexible battery approach. Testing time for

each patient varied upon the amount of assessment that was deemed necessary by the clinical neuropsychologist administering the battery of tests.

The data gathered for these analyses used archival data from these neuropsychological assessments. Data was gathered by six Ph.D. students from Ball State University under the supervision of a Ball State University professor who obtained IRB approval for this study. The students collected data from October, 2008 until July, 2010. Data were collected on 449 patients. Overall, there were 70 boxes of patient records which included 3123 patient files. Data were collected on every patient, regardless of diagnosis, from October, 2008 until January, 2010. Beginning in January, 2010, a targeted search was conducted in which only those patients with either a diagnosis of ADHD or FASD were collected for data purposes. Overall, out of the potential 3123 patient files, there were 315 patient files entered into an SPSS 15.0 database. The patient files were concurrently entered into this database as data collection was conducted.

In these analyses only those patients diagnosed with FAS, FASD, ARND, and FAE along with comorbid ADHD will be used as part of the 'ADHD/FASD' group. Those diagnosed with ADHD without comorbid FAS, FASD, ARND, or FAE will be used for the 'ADHD' group.

Instrumentation.

Wechsler Intelligence Scale for Children – Fourth Edition. The *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003) is an individually administered clinical instrument used to assess the cognitive ability of children aged 6 years, 0 months through 16 years, 11 months. The WISC-IV is a valid and reliable measure of global cognitive functioning. The mean index score for the

WISC-IV is 100 with a standard deviation of 15; the mean subtest score is 10 with a standard deviation of 3.

The WISC-IV provides a measure of general intellectual functioning and four index scores. These index scores allow comparison of clusters of related abilities: Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed. The WISC-IV has 10 core subtests and five supplemental subtests. Similarities, Vocabulary, and Comprehension are the three core subtests that comprise the Verbal Comprehension Index. The three core Perceptual Reasoning subtests are Block Design, Picture Concepts, and Matrix Reasoning. Digit Span and Letter-Number Sequencing are the two core Working Memory subtests. Coding and Symbol Search are the two core Processing Speed subtests (Wechsler, 2003b). The WISC-IV has been shown to have high validity index correlations with other measures of IQ including the *Wechsler Intelligence Scale for Children – Third Edition* (WISC-III; Wechsler, 1991). The correlations between composite scores from the WISC-IV and WISC-III ranged from .72 to .89 with overall FSIQ on each of these measures having a correlation of .89 (Wechsler, 2003b). Correlations between the WISC-IV composites and the *Wechsler Adult Intelligence Scales – Third Edition* (WAIS-III) composites ranged from .73 to .89 (Wechsler, 2003).

Verbal Comprehension Index. The WISC-IV Verbal Comprehension Index is a measure of verbal concept formation, verbal reasoning, and knowledge acquired from one's environment (Wechsler, 2003b). Tests of verbal comprehension include measures of vocabulary, verbal similarities, social reasoning and judgment, and fund of information (Quinlan, 2009). The Verbal Comprehension Index has an internal consistency overall average reliability of .94 (Wechsler, 2003b) using Fisher's z transformation. The average

corrected stability coefficient measures test-retest stability. Stability coefficients in the .90 range are excellent, those in the .80 range are good, and those stability coefficients in the .70 range are adequate (Wechsler, 2003b). The stability coefficient for the Verbal Comprehension Index is .89 (Wechsler, 2003b). The Verbal Comprehension Index has an internal validity inter-correlation index of .85 (Wechsler, 2003b) with the WISC-IV FSIQ.

Similarities. On the Similarities subtest the child is presented two words that represent common objects or concepts and describes how they are similar; this test is designed to measure verbal reasoning and concept formation (Wechsler, 2003b). The Similarities subtest assesses the ability to identify conceptual relations between concepts, a skill not specifically taught, and thus somewhat less influenced by quality of education and cultural background (Quinlan, 2009). The Similarities subtest has an internal consistency overall average reliability of .86 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Similarities subtest is .81 (Wechsler, 2003b). The Similarities subtest has an internal validity inter-correlation index of .89 (Wechsler, 2003b) with the WISC-IV Verbal Comprehension Index.

Vocabulary. The Vocabulary subtest has two sections; the first has the examiner present the child with pictures which the child is asked to name, the second part of the subtest has the child provide definitions for words that the examiner reads out loud. Vocabulary is designed to measure a child's word knowledge and verbal concept formation; it also measures a child's fund of knowledge, learning ability, long-term memory, and degree of language development (Wechsler, 2003b). Measures of vocabulary assess the breadth and precision of word knowledge and facility with

expressive language (Quinlan, 2009). The Vocabulary subtest has an internal consistency overall average reliability of .89 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Vocabulary subtest is .92 (Wechsler, 2003b). The Vocabulary subtest has an internal validity inter-correlation index of .91 (Wechsler, 2003b) with the WISC-IV Verbal Comprehension Index.

Comprehension. Comprehension tasks require the child to answer questions based on their understanding of general principles and social situations (Wechsler, 2003b). The Comprehension subtest is designed to measure verbal reasoning and conceptualization, verbal comprehension and expression, the ability to evaluate and use past experience, and the ability to demonstrate practical information (Wechsler, 2003b). The Comprehension subtest assesses the understanding of and ability to express social conventions, expectations, and societal structures (Quinlan, 2009). The Comprehension subtest has an internal consistency overall average reliability of .81 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Comprehension subtest is .82 (Wechsler, 2003b). The Comprehension subtest has an internal validity inter-correlation index of .86 (Wechsler, 2003b) with the WISC-IV Verbal Comprehension Index.

Information. Information is a subtest in which the child answers questions that address a broad range of general knowledge topics. This subtest is designed to measure a child's ability to acquire, retain, and retrieve general factual knowledge (Wechsler, 2003b). The Information subtest assesses a broad range of information that reflects broad cultural exposure and the ability to accumulate and recall information (Quinlan, 2009). The Information subtest has an internal consistency overall average reliability of .86 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the

Information subtest is .89 (Wechsler, 2003b). The Information subtest has an internal validity inter-correlation index of .77 (Wechsler, 2003b) with the WISC-IV Verbal Comprehension Index.

Word Reasoning. Word Reasoning is a subtest that has the child identify a common concept being described in a series of clues. This task measures verbal comprehension, analogical and general reasoning ability, verbal abstraction, domain knowledge, and the ability to integrate and synthesize different types of information, and generate alternative concepts (Wechsler, 2003b). The Word Reasoning subtest involves the child guessing an object from one or two descriptive cues (Quinlan, 2009). The Word Reasoning subtest has an internal consistency overall average reliability of .80 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Word Reasoning subtest is .82 (Wechsler, 2003b). The Word Reasoning subtest has an internal validity inter-correlation index of .70 (Wechsler, 2003b) with the WISC-IV Verbal Comprehension Index.

Perceptual Reasoning Index. The Perceptual Reasoning Index (PRI) summarizes functioning on tasks with perceptual processing, analysis, and synthesis. The PRI is a measure of perceptual and fluid reasoning, spatial processing, and visual-motor integration (Wechsler, 2003b). The PRI has an internal consistency overall average reliability of .92 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the PRI is .89 (Wechsler, 2003b). The Perceptual Reasoning Index has an internal validity inter-correlation index of .86 (Wechsler, 2003b) with the WISC-IV FSIQ.

Block Design. All items on the Block Design subtest have the child view a constructed model or a picture in the stimulus book, and use all white, all red, and red-and-white blocks to re-create the design within a specified amount of time. Block Design is intended to measure the ability to analyze and synthesize abstract visual stimuli (Wechsler, 2003b); it also involves nonverbal concept formation, visual perception and organization, simultaneous processing, visual-motor coordination, learning, and the ability to separate figure and ground in visual stimuli (Cooper, 1995; Groth-Marnat, 1997; Kaufman, 1994, Sattler, 2001; Wechsler, 2003b). The Block Design subtest has an internal consistency overall average reliability of .86 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Block Design subtest is .82 (Wechsler, 2003b). The Block Design subtest has an internal validity inter-correlation index of .81 (Wechsler, 2003b) with the WISC-IV Perceptual Reasoning Index.

Picture Concepts. For each item on the Picture Concepts subtest the child is presented with two or three rows of pictures and chooses one picture from each row to form a group with a common characteristic (Wechsler, 2003b). This subtest is designed to measure abstract categorical reasoning (Wechsler, 2003b). The Picture Concepts subtest has an internal consistency overall average reliability of .82 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Picture Concepts subtest is .76 (Wechsler, 2003b). The Picture Concepts subtest has an internal validity inter-correlation index of .77 (Wechsler, 2003b) with the WISC-IV PRI.

Matrix Reasoning. Matrix Reasoning requires the child to identify models and series in a set of complex visual patterns and to identify what pattern is needed to complete the stimulus (Quinlan, 2009). Matrix Reasoning tasks are good measures of

fluid intelligence, are relatively culture-fair and language-free, and do not require hand manipulation (Wechsler, 2003b). The Matrix Reasoning subtest has an internal consistency overall average reliability of .89 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Matrix Reasoning subtest is .85 (Wechsler, 2003b). The Matrix Reasoning subtest has an internal validity inter-correlation index of .84 (Wechsler, 2003b) with the WISC-IV PRI.

Picture Completion. All items on the Picture Completion subtest require the child to view a picture and then point to or name the important part missing within a specified time limit (Wechsler, 2003b). This subtest is designed to measure visual perception and organization, concentration, and visual recognition of essential details of objects (Cooper, 1995; Kaufman, 1994; Sattler, 2001; Wechsler, 2003b). Picture Completion requires the identification of missing details in pictures, a skill that is sometimes undercut by impulsivity in children with ADHD (Quinlan, 2009). The Picture Completion subtest has an internal consistency overall average reliability of .86 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Picture Completion subtest is .84 (Wechsler, 2003b). The Picture Completion subtest has an internal validity inter-correlation index of .57 (Wechsler, 2003b) with the WISC-IV PRI.

Working Memory Index. Working memory is guided by the frontal lobes, and is a component of executive functioning (Papolos & Papolos, 2002). Working Memory tasks from the Working Memory Index (WMI) require the ability to temporarily retain information in memory, perform some operation or manipulation with that information, and produce a result (Wechsler, 2003b). The WMI has an internal consistency overall average reliability of .92 (Wechsler, 2003b) using Fisher's z transformation. The stability

coefficient for the WMI is .89 (Wechsler, 2003b). The WMI has an internal validity inter-correlation index of .76 (Wechsler, 2003b) with the WISC-IV FSIQ.

Digit Span. The Digit Span subtest has two parts in which the examiner requires the child to repeat a series of digits that are read aloud. The first part entails the examiner to read a series of numbers ranging in length from 2 to 9 digits. The child is required to repeat those numbers back to the examiner in the same sequence. The second part of this subtest requires the child to repeat the series of numbers in reverse sequence. Digit Span is primarily a measure of the child's short-term sequential auditory memory and attention (Sattler, 2001). In addition, the subtest assesses a child's ability to retain several elements that have no logical relationship with one another, manipulate that information, and repeat it back in a sequentially correct order; therefore, requiring working memory. The Digit Span subtest has an internal consistency overall average reliability of .87 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Digit Span subtest is .83 (Wechsler, 2003b). The Digit Span subtest has an internal validity inter-correlation index of .86 (Wechsler, 2003b) with the WISC-IV WMI.

Letter-Number Sequencing. Letter-Number Sequencing requires the child to sequentially order a series of numbers and letters that are orally presented in a specified random order (Sattler, 2001). The Letter-Number Sequencing subtest involves attention, information processing, and it also highly emphasizes working memory. The Letter-Number Sequencing subtest is a challenging working memory task (Quinlan, 2009). The Letter-Number Sequencing task requires the sequential manipulation of not only letters but also numbers, requiring a more effortful processing of the information being presented. The Letter-Number Sequencing subtest has an internal consistency overall

average reliability of .90 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Letter-Number Sequencing subtest is .83 (Wechsler, 2003b). The Letter-Number Sequencing subtest has an internal validity inter-correlation index of .86 (Wechsler, 2003b) with the WISC-IV WMI.

Arithmetic. The Arithmetic subtest requires the examinee to answer simple to complex problems involving arithmetic concepts and numerical reasoning (Sattler, 2001). The Arithmetic subtest requires the use of concentration and attention in conjunction with knowledge of numerical operations and holding information in working memory (Sattler, 2001). When Arithmetic problems involve more than one calculation step, the subtest can be substantially affected by problems of focus and concentration (Quinlan, 2009). The Arithmetic subtest has an internal consistency overall average reliability of .88 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Arithmetic subtest is .79 (Wechsler, 2003b). The Arithmetic subtest has an internal validity inter-correlation index of .57 (Wechsler, 2003b) with the WISC-IV Working Memory Index.

Processing Speed Index. The Processing Speed Index (PSI) provides a measure of the child's ability to quickly and correctly scan, sequence, or discriminate simple visual information (Wechsler, 2003b). The subtests comprising the PSI are work output measures. These subtests are multi-faceted; involving visual, spatial, motor, and sequencing abilities. Speeded tests such as those on the PSI are vulnerable to numerous influences, both from functional and neurological sources. The PSI has an internal consistency overall average reliability of .88 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the PSI is .86 (Wechsler, 2003b). The PSI has

an internal validity inter-correlation index of .70 (Wechsler, 2003b) with the WISC-IV FSIQ.

Coding. The Coding subtest requires that the examinee copy symbols paired together with other unrelated symbols. A child is assessed on the Coding subtest on one of two tests depending on their age. The Coding task either has a set of shapes or a set of numbers from 1 to 9 associated with one unrelated symbol. The child is given a specific amount of time to correctly pair each shape or number with its corresponding symbol. Coding assesses the child's ability to learn an unfamiliar task, and it involves speed and accuracy of visual-motor coordination, speed of mental operation (processing speed), attentional skills, visual acuity, visual scanning and tracking (repeated visual scanning between the code key and answer spaces), short-term memory for new learning (paired-associate learning of an unfamiliar code), cognitive flexibility (in shifting rapidly from one pair to another), handwriting speed, and possibly motivation (Sattler, 2001). The Coding subtest has an internal consistency overall average reliability of .85 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Coding subtest is .84 (Wechsler, 2003b). The Coding subtest has an internal validity inter-correlation index of .88 (Wechsler, 2003b) with the WISC-IV PSI.

Symbol Search. Symbol Search is a test in which the examinee scans a list of shapes and then decides whether those particular shapes are present in a second presented list of shapes. This task involves perceptual discrimination, speed and accuracy, attention and concentration, short-term memory, and cognitive flexibility (in shifting rapidly from one array to the next; Sattler, 2001). The Symbol Search subtest assesses speed, but with reduced requirements for visuomotor coordination (Quinlan, 2009). The Symbol Search

subtest has an internal consistency overall average reliability of .79 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Symbol Search subtest is .80 (Wechsler, 2003b). The Symbol Search subtest has an internal validity inter-correlation index of .87 (Wechsler, 2003b) with the WISC-IV PSI.

Cancellation. The Cancellation subtest requires the examinee to scan a structured and then an unstructured array of pictures and mark out certain pre-arranged pictures within a certain amount of time. Cancellation assesses processing speed, vigilance, visual selective attention, and visual neglect (Bate et al., 2001). The Cancellation subtest has an internal consistency overall average reliability of .79 (Wechsler, 2003b) using Fisher's z transformation. The stability coefficient for the Cancellation subtest is .79 (Wechsler, 2003b). The Cancellation subtest has an internal validity inter-correlation index of .41 (Wechsler, 2003b) with the WISC-IV PSI. *Vineland Adaptive Behavior Scales*

The *Vineland Adaptive Behavior Scales* (VABS; Sparrow, Balla, & Cicchetti, 1984) is an individually administered measure of adaptive functioning. Each question from the VABS is rated on a Likert-type scale using; 2 (usually), 1 (sometimes or partially), 0 (never), or DK (Don't Know). The mean score for each composite is 100 with a standard deviation of 15. The Vineland consists of four broad domains including Communication, Daily Living Skills, Socialization, and Motor Skills. This form also includes a Maladaptive Behavior Domain that assesses overall problem behaviors. The mean score for each composite is 100 with a standard deviation of 15.

The content validity of the VABS is supported by the thorough procedures used in the original development of the items which included national standardization procedures, a thorough review of other adaptive behavior scales, and literature searches

conducted on adaptive behavior (Sparrow, Balla, & Cicchetti, 1984b). Criterion-related validity is high between the VABS and other adaptive behavior scales. For instance, the VABS was compared with the *Revised Vineland* and the *Vineland Social Maturity Scale*; validity indices were .55 on measures of criterion-related validity for each of these measures (Sparrow, Balla, & Cicchetti, 1984b). The VABS was also compared with intelligence tests to assess criterion-related validity. The correlations between the VABS and the *Kaufman Assessment Battery for Children* (K-ABC; Kaufman & Kaufman, 1983) ranged from .08 to .52 with most correlations being below .20 (Sparrow, Balla, & Cicchetti, 1984b) suggesting that the VABS assesses a construct independent of intellectual functioning.

Communication Domain. The Communication Domain assesses Receptive, Expressive, and Written Communication. Measures of split-half reliability aimed at assessing the internal validity of the Communication Domain have a median of .89 (Sparrow, Balla, & Cicchetti, 1984b) indicating good internal reliability. Test-retest reliability coefficients for the Communication Domain were .99 (Sparrow, Balla, & Cicchetti, 1984b).

Receptive. The Receptive Communication Domain assesses how the child listens and pays attention, and what he or she understands (Sparrow, Cicchetti, & Balla, 2005). Examples of questions on the Receptive Communication Domain include; "Listens to instructions," and "Responds to his or her name (for example, turns toward speaker, smiles, etc.)." Measures of split-half reliability for the Receptive Communication Domain were .75 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Expressive. The Expressive Communication Domain assesses expressive language, and how the child uses words and sentences to gather and provide information (Sparrow, Cicchetti, & Balla, 2005). Examples of questions on the Expressive Communication Domain include, "Points to objects he or she wants that are out of reach," and "Uses phrases with a noun and a verb." Measures of split-half reliability for the Expressive Communication Domain were .75 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Written. The Written Communication Domain assesses what the individual understands about how letters make words, and what he or she reads and writes (Sparrow, Cicchetti, & Balla, 2005). Examples of Written Communication Domain questions include, "Recognizes own name in printed form," and "Prints or writes own first and last name from memory." Measures of split-half reliability for the Written Communication Domain were .84 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Daily Living Skills Domain. The Daily Living Skills Domain assesses Personal, Domestic, and Community living skills. Split-half reliability indexes for the Daily Living Skills Domain were .90 (Sparrow, Balla, & Cicchetti, 1984b) indicating good reliability across all age ranges. Test-retest reliability coefficients for the Daily Living Skills domain were .99 (Sparrow, Balla, & Cicchetti, 1984b).

Personal. The Personal Daily Living Skills Domain assesses how the child eats, dresses, and practices personal hygiene (Sparrow, Cicchetti, & Balla, 2005). Examples of questions from the Personal Daily Living Skills Domain include, "Asks to use toilet," and "Washes and dries hair." Split-half reliability for the Personal Daily Living Skills Domain were .69 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Domestic. The Domestic Domain assesses what household chores the individual performs (Sparrow, Cicchetti, & Balla, 2005). Examples of questions from the Domestic Daily Living Skills Domain include, "Is careful around hot objects," and "Plans and prepares main meal of the day." Split-half reliability for the Domestic Daily Living Skills Domain were .78 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Community. The Community Domain assesses how the individual uses time, money, the telephone, the computer, and assesses potential job skills (Sparrow, Cicchetti, & Balla, 2005). Examples of questions from the Community Daily Living Skills Domain include, "Talks to familiar person on the telephone," and "Looks both ways when crossing the street." Split-half reliability for the Community Daily Living Skills Domain were .78 across all age samples (Sparrow, Balla, & Cicchetti, 1984b).

Socialization Domain. The Socialization Domain assesses Interpersonal Relationships, Play and Leisure Time, and Coping Skills. Split-Half reliability indexes were .86 across all age samples for the Socialization Domain (Sparrow, Balla, & Cicchetti, 1984b). Test-retest reliability coefficients for the Socialization Domain were .98 (Sparrow, Balla, & Cicchetti, 1984b).

Interpersonal Relationships. The Interpersonal Relationships composite is composed of questions that assess how an individual interacts with others (Sparrow, Cicchetti, & Balla, 2005). This composite consists of questions ranging from "Demonstrates friendship-seeking behavior with others the same age," to "Has best friend or shows preference for certain friends (of either sex) over others." Split-half reliability for the Interpersonal Relationships Socialization composite is .74 across all age ranges (Sparrow, Balla, & Cicchetti, 1984b).

Play and Leisure Time. The Play and Leisure Time composite is composed of questions that assess how an individual plays and uses leisure time (Sparrow, Cicchetti, & Balla, 2005). Example questions from this domain include, "Plays near another child, each doing different things," and "Shares toys or possessions without being asked." Split-half reliability for the Play and Leisure Time Socialization composite were .71 across all age ranges (Sparrow, Balla, & Cicchetti, 1984b).

Coping Skills. The Coping Skills composite is composed of questions that assess how an individual demonstrates responsibility and sensitivity to others (Sparrow, Cicchetti, & Balla, 2005). Examples from this domain include, "Ends conversations appropriately," and "Shows understanding that gentle teasing with family and friends can be a form of humor or affection." Split-half reliability for the Coping Skills Socialization composite were .76 across all age ranges (Sparrow, Balla, & Cicchetti, 1984b).

Motor Skills Domain. The Motor Skills Domain assesses Gross and Fine Motor Skills for those patients up to 6 years old. Split-half reliability indexes for the Motor Skills Domain were .83 across these age ranges (Sparrow, Balla, & Cicchetti, 1984b). Test-retest reliability coefficients for the Motor Skills Domain were .98 (Sparrow, Balla, & Cicchetti, 1984b).

Gross. The Gross Motor Skills Domain assesses how the individual uses their arms and legs for movement and coordination (Sparrow, Cicchetti, & Balla, 2005). Examples of questions from the Gross Motor Skills Domain include, "Stands alone for 1 to 3 minutes," and "Catches tennis or baseball-sized ball, moving to catch it if necessary." Split-half reliability for the Gross Motor Skills composite were .78 across all possible age ranges (Sparrow, Balla, & Cicchetti, 1984b).

Fine. Fine Motor Skills is an examination of how an individual uses their hands and fingers to manipulate objects (Sparrow, Cicchetti, & Balla, 2005). Examples of questions from the Fine Motor Skills Domain include, "Squeezes squeaky toy or object," and "Turns book or magazine pages one by one." Split-half reliability for the Fine Motor Skills composite were .78 across all possible age ranges (Sparrow, Balla, & Cicchetti, 1984b).

Statistical Procedures and Data Analysis. Altogether, there were two separate analyses that composed this larger investigation of cognitive and adaptive skills deficits in children with ADHD/FASD and ADHD. Overall, there were scores from 228 participants used for the analyses in this investigation. Analyzing the cognitive and adaptive skills of those with ADHD/FASD and ADHD will help further the field of neuropsychology by aiding in differential diagnostics, improving psychopharmacological treatment, and aiding in intervention strategies. Thus, researchers must compare alcohol-exposed individuals to similar clinical groups, rather than outlining deficits only in relation to typically-developing children (Crocker et al., 2009). Therefore, the analyses conducted between those with ADHD/FASD to those with ADHD will help researchers and clinicians further understand the deficits seen in each of these populations.

Cognitive and Adaptive Skills Deficits in Children with ADHD and FASD. To accomplish the first goal of assessing the similarities and differences in cognitive and adaptive skills functioning between the ADHD/FASD group and the ADHD group, a Multivariate Analysis of Variance (MANOVA) with a follow-up Discriminant Analysis was conducted. In order to account for an effect of gender, stimulant medication, and ethnicity these variables were independently entered as fixed factors in MANOVA

analyses. Neither stimulant medication nor ethnicity accounted for a significant amount of the difference between the diagnostic groups. However, there were significant gender effects seen in cognitive abilities between the two diagnostic groups. Therefore, gender was used as an independent variable in the analyses. In order to address the question of diagnostic and gender differences in cognitive and adaptive skills the 'SPSS 15.0' statistical package was used to analyze the differences between the ADHD and ADHD/FASD groups on cognitive skills deficits as represented by the WISC-IV composites and subtests. Adaptive skills deficits were measured by the VABS Communication, Socialization, and Daily Living Skills Composites. The main question being addressed by this statistical analysis was, "Is there a significant difference in cognitive or adaptive skills functioning between those with ADHD/FASD and ADHD?" Following this investigation a Discriminant Analysis was conducted. The question being addressed by this analysis included, "Which composites from the cognitive and adaptive measures most greatly contribute to the overall differences between the ADHD/FASD and ADHD groups?" It was hypothesized that children with comorbid ADHD/FASD would have lower scores on the WISC-IV and VABS compared against children with ADHD.

Diagnostic Group Membership of Children with ADHD and FASD. To accomplish the second goal of assessing the best cognitive and adaptive skills predictors of group membership into the ADHD/FASD or ADHD group, a Classification and Regression Tree (CART) analysis was conducted using the 'R 2.10' statistical analysis package. This analysis will hopefully elucidate differential patterns of performance, add to the growing knowledge of neuropsychological and behavioral profiles associated with

prenatal alcohol exposure, and ultimately improve differential diagnosis between these populations. A CART analysis will take analytical information similar to that gathered from the Discriminant Analysis and represent this information in an easy-to-follow flow chart format. This CART analysis provided a flow chart of group membership into either the ADHD/FASD group or ADHD group based on each of these group's cognitive and adaptive skills strengths and weaknesses. This flow chart will be helpful for clinicians practicing in environments where they encounter children with FASD and ADHD on a regular basis and need to make diagnostic decisions regarding each of these groups.

Chapter 4

Results

The purpose of this study was to evaluate the cognitive and adaptive skills differences among children with ADHD/FASD and children with ADHD. To accomplish this, comparisons were made among children with comorbid ADHD/FASD and those with ADHD. Initial analyses were conducted on these diagnostic groups to discover if there were significant effects of race or prescription medication in the analyses. Multivariate Analyses of Variance including each of these variables failed to show a significant effect for either ethnicity (Table 3.1.) or stimulant medication (Table 3.2.). Data included the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003) and the *Vineland Adaptive Behavior Scales* (VABS; Sparrow, Balla, & Cicchetti, 1984) which provided evidence of several cognitive and adaptive skills. It was hypothesized that detection of differences among children with these divergent diagnoses will help improve psychopharmacological treatment and guide interventions. If significant cognitive and adaptive skills differences do not exist then this information may be indicative of the considerable level of cognitive and adaptive skill variability among those with ADHD/FASD which may make this group's deficits quantifiably equitable to those children with ADHD.

Following a presentation of the descriptive data for the study participants, the results are discussed in terms of the seven research questions. This chapter is divided into six sections: (1) description of the sample; (2) results of the Multivariate Analysis of Variance tests; (3) results of the Discriminant Analysis; (4) results of the Classification and Regression Tree; (5) summary of the statistical results in terms of the research questions; and (6) conclusions.

Description of the Sample. In this study there were 81 children with ADHD/FASD and 147 children with ADHD who were administered the WISC-IV and Vineland. The sample of children for this study did not include those who were also diagnosed with mental retardation. Based on a multitude of literature showing the cognitive and adaptive skills difference that are evident between males and females it was hypothesized that there may be gender effects present among these groups; therefore, the two diagnostic groups (children with ADHD and children with ADHD/FASD) were further broken down based on gender resulting in four groups being studied in this investigation. Overall there were four groups investigated in this study including males with ADHD, females with ADHD, males with ADHD/FASD, and females with ADHD/FASD.

Table 4.1 provides the descriptive statistics including gender, race, and age for the ADHD and ADHD/FASD samples. Overall, there were more males diagnosed with ADHD and ADHD/FASD and the majority of the sample in this study was Caucasian. The sample that was collected for this study was quite similar to the makeup of the United States population according to the U.S. Census Bureau in 2011. The American population is 75.1% Caucasian compared to 78.5% in this study (179 of 228). Black or

African Americans make up 12.3% of the American population compared to 11.8% in this study (27 of 228). The American population is 2.4% Bi-racial compared to 5.7% in this study (13 of 228). The Hispanic population in America is 3.3% compared to 2.6% in this study (6 of 228).

Table 4.1.

Demographic Statistics for the Overall Sample

	ADHD		ADHD/FASD	
	Male (n=105)	Female (n=42)	Male (n=46)	Female (n=35)
Race				
Caucasian	82 (35.9%)	32 (14.0%)	39 (17.1%)	26 (11.4%)
African American	10 (4.4%)	5 (2.2%)	7 (3.1%)	5 (2.2%)
Bi-Racial	8 (3.5%)	4 (1.8%)	---	1 (0.4%)
Hispanic	3 (1.3%)	1 (0.4%)	---	2 (0.8%)
'Other'	2 (0.8%)	---	---	1 (0.4%)
Age (Mean, SD)	10.1 (2.9)	10.1 (3.4)	10.5 (2.8)	9.2 (2.5)
Prescribed Stimulants	55 (52.3%)	14 (33.3%)	26 (56.5%)	20 (57.1%)

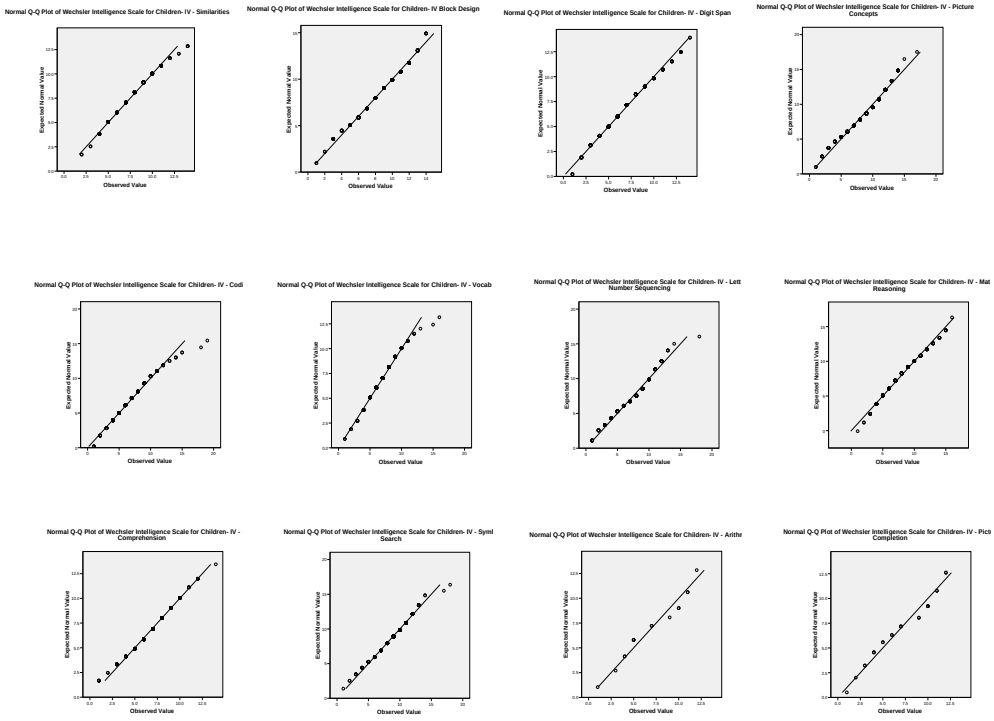
Multivariate Analysis of Variance. Two Multivariate Analyses of Variance (MANOVAs) were used in the current study to investigate the cognitive and adaptive skills differences among the children in the four groups using the subtests of the WISC-IV and the composites of the VABS. MANOVA is designed to look at several dependent variables (outcomes) simultaneously and so is a multivariate test (multivariate means 'many variables'; Field, 2005). The dependent variables being analyzed using the MANOVA in this study included the WISC-IV subtests and the VABS composites. The independent variables in this study included the four ADHD or ADHD/FASD groups.

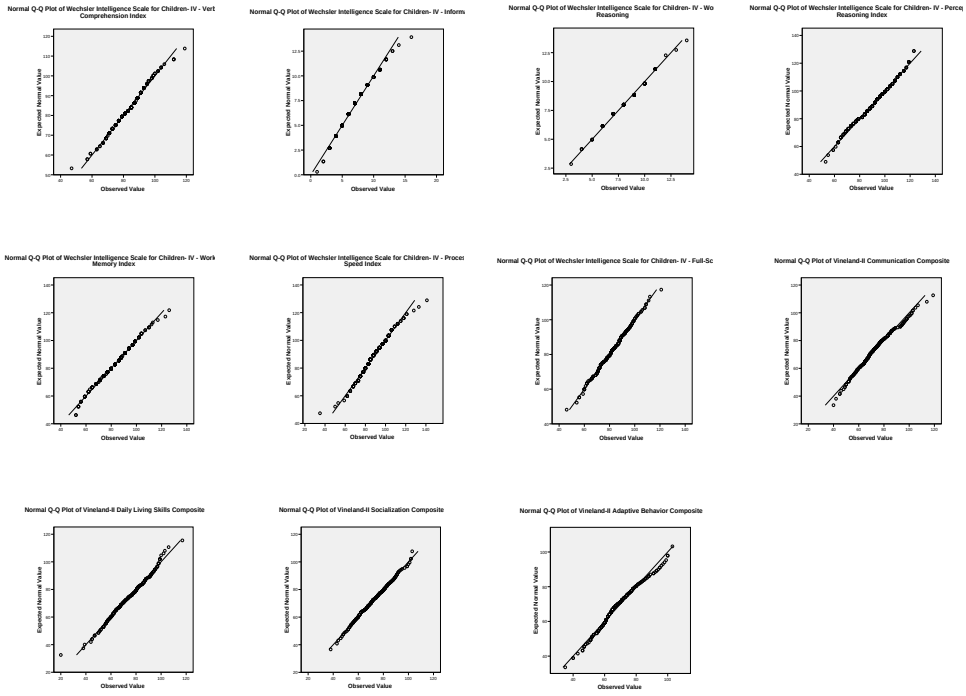
Assumptions of MANOVA Statistical Tests. Before the results of the MANOVA could be analyzed, it was important to assess whether any of the underlying assumptions of this statistical procedure were violated. There are six main assumptions of MANOVA. A violation of an assumption increases the risk that a significant difference would be wrongly attributed to one of the dependent variables. In this case, that a WISC-IV composite or subtest or VABS composite score would statistically predict a difference among the two groups of children with ADHD/FASD and two groups of children with ADHD.

The first assumption of MANOVA is independence. Each of the observations, or test composites and subtests, should be statistically independent (Field, 2005). This assumption is met by the fact that each of the patient's data used in this study was gathered by the neuropsychologist who was conducting assessments on each patient without other patients influencing the assessments. The second assumption of the MANOVA is random sampling (Field, 2005). The sample that was derived for this analysis consisted of clinic-referred patients from Fort Wayne, Indiana. Therefore, the patients in this study consisted of a generally restricted Midwestern sample and the assumption of random sampling was not met. The third assumption of MANOVA is multivariate normality. In MANOVA we assume that the dependent variables collectively have multivariate normality within groups (Field, 2005). Multivariate normality is essentially a normal distribution across multiple variables. The assumption of multivariate normality cannot be tested and the only practical solution is to check this assumption for each dependent variable. Therefore, univariate normality, as represented by Q-Q plots for each of the WISC-IV subtests and Vineland composites, was checked.

According to the univariate normality of each of the individual WISC-IV composites, WISC-IV overall IQ, and VABS composites, the assumption of Multivariate normality appears to be met.

Multivariate Analysis of Variance assumes that the dependent variables collectively have multivariate normality within groups (Field, 2005). Multivariate normality is essentially a normal distribution across multiple variables. The assumption of multivariate normality cannot be tested and the only practical solution is to check this assumption for each dependent variable. Therefore, the following graphs are depictions of the univariate normality as represented by Q-Q plots for each of the WISC-IV composites and subtests as well as the Vineland composites.





According to the univariate normality of each of the individual WISC-IV composites and subtests as well as the VABS composites the assumption of Multivariate normality appeared to be met.

The fourth assumption of MANOVA is homogeneity of covariance matrices (Field, 2005). In order to test this assumption Levene's test must be used to take account of the covariances among groups on each of the dependent variables. To confirm this assumption, the values for Levene's test should not be significant for the dependent variables. The homogeneity of covariance among the WISC-IV subtests, and VABS composites is shown below (Tables 4.2. and 4.3.) as represented by Levene's test based on the mean. As indicated by the absence of significance on the Levene's test the assumption of homogeneity of covariance was sufficiently met for the WISC-IV. However, Levene's test was significant for the Vineland Communication Composite.

Table 4.2.

Levene's Test of Significance for the WISC-IV

Subtests	Significance
Block Design	.603
Similarities	.101
Digit Span	.732
Picture Concepts	.687
Coding	.308
Vocabulary	.397
L-N Sequencing	.669
Matrix Reasoning	.173
Comprehension	.780
Symbol Search	.107
Information	.311

Note. Any subtest that is significant violates the assumption of homogeneity of covariance.

Table 4.3.

Levene's Test of Significance for the Vineland

Composite	Significance
Communication	.019*
Daily Living Skills	.869
Socialization	.191
Overall	.158

Note: * indicates a violation of homogeneity of covariance.

According to Field (2005), Levene's test does not take account of the covariances and so the variance-covariance matrices should be compared between groups using Box's test. This test should be non-significant if the matrices are the same. According to Box's test, the WISC-IV MANOVA meets the assumption of homogeneity of covariance but the Vineland MANOVA fails to meet this assumption. Given that the Vineland MANOVA fails to meet the assumption of homogeneity of covariance among dependent variables this MANOVA analysis was unable to be reliably interpreted (see Table 4.4) and a Univariate Analysis of Variance (ANOVA) was used in this study to analyze adaptive skills deficits between diagnostic groups.

Table 4.4.

Box's M Test of Variance-Covariance

Measure	Significance
WISC-IV	.585
Vineland	.002*

Note: * indicates a violation of homogeneity of variance-covariance.

Descriptive Statistics. Table 4.5 represents the mean scores and standard deviations of each of the four groups in the sample as they performed on the WISC-IV subtests. Table 4.5 is purely descriptive in nature as there are no statistical analyses taking place at this stage. The WISC-IV subtests include measures of Verbal Comprehension (Similarities, Comprehension, Information), Working Memory (Digit Span, Letter-Number Sequencing), Perceptual Reasoning (Block Design, Picture Concepts, Matrix Reasoning), and Processing Speed (Coding, Symbol Search). The mean subtest score for each of these measures is ten with a standard deviation of three.

Table 4.5.

Descriptive Statistics for the WISC-IV Subtests

	Females		Males	
Subtest	ADHD (n=42)	ADHD/FASD (n=35)	ADHD (n=105)	ADHD/FASD (n=46)
Block Design	8.24 (2.96)	7.09 (3.05)	8.48 (2.58)	8.61 (2.94)
Similarities	7.37 (2.01)	7.09 (2.71)	7.37 (2.14)	7.43 (2.04)
Digit Span	7.34 (2.19)	6.82 (2.81)	6.83 (2.82)	6.37 (2.75)
Picture Concepts	9.98 (3.03)	7.21 (2.96)	8.75 (3.01)	8.41 (3.31)
Coding	8.71 (3.14)	6.82 (3.17)	6.54 (2.68)	6.37 (2.74)
Vocabulary	7.59 (2.33)	6.35 (2.73)	6.55 (1.93)	6.59 (2.18)
L-N Sequencing	7.54 (3.35)	7.03 (2.82)	7.38 (3.20)	6.50 (3.19)
Matrix Reasoning	9.17 (3.09)	7.50 (3.33)	8.06 (2.94)	7.57 (2.38)
Comprehension	7.63 (2.03)	5.74 (2.16)	7.19 (2.26)	6.43 (2.41)
Symbol Search	10.10 (2.28)	8.76 (3.04)	8.34 (2.45)	8.61 (2.67)
Information	7.41 (1.87)	6.62 (2.47)	7.46 (2.43)	6.41 (2.75)

Note. Derived scaled scores range from 1 to 19. Mean scaled score is 10.00 with a standard deviation of 3.00. Standard deviations are shown in parentheses.

The following tables describe the average performance from each of the groups in this sample on the Vineland. Each of these Vineland measures is a composite score. The Communication Domain is derived from Receptive, Expressive, and Written Communication abilities. The Daily Living Skills Domain is comprised of Personal, Domestic, and Community skills. The Socialization Domain is derived from Interpersonal Relationships, Play and Leisure Time, and Coping Skills. The Overall Adaptive Skills Domain is comprised of the Communication, Daily Living Skills, and Socialization Domains. Mean scores on these composites are 100 with a standard deviation of fifteen.

Table 4.6.

Descriptive Statistics for the Vineland Composites

	Females		Males	
Composite	ADHD (n=42)	ADHD/FASD (n=35)	ADHD (n=105)	ADHD/FASD (n=46)
Communication	78.02 (17.56)	72.47 (13.37)	72.59 (12.72)	68.96 (13.35)
Daily Living Skills	77.83 (14.10)	72.71 (13.17)	74.74 (15.60)	68.84 (14.37)
Socialization	74.00 (14.16)	70.79 (10.94)	72.29 (12.50)	70.07 (12.83)
Overall	72.12 (14.26)	67.15 (10.64)	68.39 (11.56)	64.71 (12.41)

Note. Derived standard scores range from 19 to 161. Mean standard score is 100.00 with a standard deviation of 15.00. Standard deviations are shown in parentheses.

Multivariate Analysis of Variance. Analyses of the cognitive and adaptive skills differences for the four groups of children with ADHD and ADHD/FASD on the WISC-IV subtests and VABS composites were conducted using MANOVA. There were two MANOVAs conducted. The first MANOVA analyzed the effects of diagnosis, gender, and the interaction of diagnosis by gender on each of the WISC-IV subtests. The second MANOVA analyzed the effects of diagnosis, gender, and the interaction effect of diagnosis by gender on the Vineland Communication, Daily Living Skills, and Socialization composites. The WISC-IV and Vineland were analyzed using two separate MANOVAs due to the fact that these assessment tools assessed two completely separate constructs; cognitive abilities and adaptive skills, respectively. The WISC-IV and Vineland were also broken up into two separate MANOVAs in order to decrease the risk of violating the assumption of homogeneity of covariance.

Table 4.7 shows the results of the first MANOVA through F-ratios and the significance values of these F-ratios. An F-ratio is the ratio of the average variability in the data that a given model can explain to the average variability unexplained in that same model (Field, 2005). It is used to test for overall differences between group means. Each group mean value is assigned a significance value. Significance values under .05 are considered significant and indicate a good predictor of difference between the groups being studied. Significance values under .01 indicate very good predictors of significant differences between groups.

Following up a MANOVA with an ANOVA in the manner above is one way of investigating group differences on dependent variables. However, ANOVAs must be treated cautiously as a significant MANOVA is likely to be accompanied by at least one significant ANOVA; however, the relationship between dependent variables is still important and it is vital to investigate the nature of the relationship between dependent and independent variables after a significant MANOVA (Field, 2005). Discriminant Analysis (DA) is useful to understand the differences between groups, to identify which variables best capture group differences, to describe the dimensionality of groups, or to test stage theories or taxonomies, (Betz, 1987; Sherry, 2010). Therefore, a DA was used to more fully analyze the differences between groups.

Table 4.7.

Multivariate Analysis of Variance Results for the WISC-IV Subtests

	Diagnosis		Gender		DxG	
Subtest	MS	F (1,227)	MS	F(1, 227)	MS	F (3, 225)
Block Design	12.33	1.57	36.07	4.59*	19.28	2.45
Similarities	3.92	0.81	0.01	0.01	5.86	1.22
Digit Span	11.19	1.54	10.90	1.50	0.04	0.01
Picture Concepts	112.83	11.96**	0.01	0.00	69.19	7.34**
Coding	49.33	6.03*	80.33	9.82**	34.32	4.20*
Vocabulary	16.71	3.47	7.51	1.55	18.84	3.91*
L-N Sequencing	22.50	2.24	5.50	0.54	1.63	0.16
Matrix Reasoning	54.82	6.40**	12.78	1.49	16.17	1.89
Comprehension	82.35	16.41**	0.76	0.15	15.29	3.05
Symbol Search	13.24	2.01	42.81	6.50**	29.99	4.55*
Information	6.79	6.79**	0.30	0.05	0.73	0.13
OMNIBUS	**386.01**	**2.55****	**196.98**	**2.82****	**211.34**	**2.23***

Note. F values indicate overall differences between group means based on a known probability distribution (the F-distribution); p values are a standardized measure of the strength of relationship between variables (also known as Pearson's correlation coefficient; Field, 2005). *p < .05. **p < .01. d is Cohen's measure of effect size. MS is Mean Square calculation.

The first MANOVA analyzing the individual subtests of the WISC-IV indicated that there was an overall omnibus significance value for diagnosis [F (1, 227) = 2.55; p < .01], gender [F (1, 227) = 2.82; p < .01], and diagnosis by gender [F (3, 227) = 2.23; p = .01]. This means that there is a significant difference between those children diagnosed with ADHD/FASD and ADHD on cognitive ability, there is also a significant difference between genders on cognitive abilities, and finally, there is a significant difference

between all four groups (males with ADHD/FASD, males with ADHD, females with ADHD/FASD, and females with ADHD) on cognitive ability as measured by the WISC-IV.

Although analyzing univariate ANOVAs from a MANOVA is not an optimal procedure the following is an interpretation of the results presented in Table 4.7. The first MANOVA indicated that diagnosis of ADHD or ADHD/FASD is a significant predictor of how a child will perform on the Picture Concepts, Coding, Matrix Reasoning, Comprehension, and Information subtests. This table showed that gender was a significant predictor of performance on the Block Design, Coding, and Symbol Search subtests. Finally, the interaction of gender by diagnosis shows a significant difference of performance on the Picture Concepts, Coding, Vocabulary, and Symbol Search subtests.

A second MANOVA was conducted in order to examine the effects of diagnosis, gender, and the interaction of diagnosis by gender on the Vineland Communication, Daily Living Skills, and Socialization composites. As previously mentioned, the results of this MANOVA were unable to be reliably interpreted due to a violation of the assumption of homogeneity of variance (Box's M, see Table 4.4). However, although these results are unreliable the overall omnibus MANOVA results for diagnosis were shown to be insignificant [$F(1, 227) = 1.92$; $p > .05$], as were gender [$F(1, 227) = 1.487$; $p > .05$], and the diagnosis by gender interaction [$F(3, 227) = 0.33$; $p > .05$]. Although the MANOVA analyzing each of the Vineland composites was unable to be reliably interpreted, the Vineland Overall Adaptive Behavior Composite is an amalgamation of each of these composites and is a valid and reliable indicator of overall adaptive skills.

Univariate Analysis of Variance. An overall MANOVA was unable to be used to analyze adaptive skills in this study due to a violation of homogeneity of covariance among the four VABS composites. In order to analyze overall adaptive skills as measured by the Vineland Overall Adaptive Behavior Composite, a Univariate Analysis of Variance (ANOVA) was used to quantify the differences among the four groups. An ANOVA performs the same function as a MANOVA except that with ANOVA only one dependent variable is being used to predict significant group differences from the independent variables. Another advantage of using an ANOVA is that it reduces the likelihood that a violation of homogeneity of covariance would be committed.

The effects of diagnosis, gender, and the interaction of diagnosis by gender on overall adaptive skills were analyzed using an ANOVA. The results of the ANOVA indicate that there was a statistically significant difference between children diagnosed with ADHD or ADHD/FASD [$F (1, 227) = 6.48$; $p = .01$]. However, there was not a significant effect of gender [$F (1, 227) = 2.71$; $p > .05$] or an interaction between diagnosis and gender [$F (3, 227) = 0.22$; $p > .05$].

Discriminant Analysis. Following the MANOVA, a Discriminant Analysis (DA) was performed to identify which of the WISC-IV subtests best accounted for group membership into the ADHD/FASD group or the ADHD group. The DA will help to determine the dependent variables that can best predict group membership. According to Finch (2010), DA is a tool commonly used for differentiating among two or more groups based on two or more predictor variables; DA works by finding one or more linear combinations of the predictors that yield maximal difference among the groups. Four groups are formed in this study when examining diagnosis and gender. One common goal

of researchers using DA is to characterize the nature of group differences by interpreting the contributions of the individual predictors (Finch, 2010) and use group membership to predict or describe scores on continuous variables (Sherry, 2010). A DA is a useful follow-up test to MANOVA as a means of seeing how a set of variables allows for groups of cases to be discriminated (Field, 2005).

The first step in analyzing a DA is to evaluate the statistical significance of the Discriminant functions (also called canonical Discriminant functions; Sherry, 2010). The first function provides the best separation between the groups while the following functions parcel out the shared variance from the previous functions. The number of functions is equal to *k* (groups) -1 (Sherry, 2010). In order to test the significance of the DA, the Wilk's Lambda statistic is examined, where smaller values indicate that the variables differentiate between the groups better (Sherry, 2010).

Table 4.8.

Statistical Significance of the Discriminant Functions

Test of Functions	Wilk's Lambda	Chi-Square	Significance
1 through 3	.683	81.06	<.01
2 through 3	.829	39.91	.01
3	.938	13.61	.14

Group membership between the four groups in this study (males with ADHD, females with ADHD, males with ADHD/FASD, females with ADHD/FASD) was found to be significantly related to performance on the WISC-IV subtests. Function one is a statistically significant function [Wilk's' Lambda = .683; F(3, 225) = .000] and accounts

for the most variance (51.9%) among the four groups as shown below in the table outlining the eigenvalues of the DA.

Table 4.9.

Eigenvalues of the Discriminant Functions

Function	Eigenvalue	% of Variance	Cumulative %	Correlation
1	.214	51.9	51.9	.420
2	.132	32.0	83.9	.341
3	.066	16.1	100.0	.249

Table 4.10 represents the structure coefficients of the WISC-IV subtests and their respective ability to discriminate group membership. The following structure coefficients represent maximized group differences as a linear combination of the predictor variables (Finch, 2010; Huberty & Olejnik, 2006). The Structure Coefficients (SCs) can be interpreted as the correlation between the discriminant variable (group membership) and the predictors (WISC-IV subtests; Finch, 2010; Stevens, 2000). Larger values of the SCs suggest greater association with the linear combination for which the groups are differentiated and can thus be thought of as indicators of the relative importance of each predictor in overall group separation (Finch, 2010).

Table 4.10.

Discriminant Analysis Results for the WISC-IV Subtests

Subtests	Pooled Within-Groups Correlations
Coding	.628*
Symbol Search	.548*
Vocabulary	.381*
Picture Concepts	.332*
Matrix Reasoning	.329*
Comprehension	.195
Digit Span	.177
Similarities	.128
Letter-Number Sequencing	.075
Information	.035
Block Design	-.083

Note. Wilk's Lambda indicated that Function 1 was significant at the $p < .01$ level; accounting for 51.9% of the variance in relative contribution of group separation among cognitive functioning scores from this sample.
* = .300 or greater. The .300 cutoff was used as a threshold to characterize the magnitude of individual dependent variable contribution to group separation as suggested by Finch (2010), Tabachnick & Fidell (2001), and Pedhazur (1997).

From the DA it is shown that the best predictor of group membership into the ADHD/FASD or ADHD groups was WISC-IV Coding, with WISC-IV Symbol Search, Vocabulary, Picture Concepts, and Matrix Reasoning also being significant predictors of group membership. Significance values in DAs are much like Beta Weights used in regression with the higher the value on this Discriminant Analysis the more likely the dependent variable is able to predict membership into the independent variable group.

Table 4.11 shows each of the best predictors of group membership according to the DA and the descriptive statistics for each of these subtests on the WISC-IV. As can be seen by the table females with ADHD performed the highest on each of the five subtests. For the Coding subtest the greatest discrepancy in performance was between females with ADHD and males with ADHD/FASD. For the Symbol Search subtest the greatest discrepancy was between females with ADHD and males with ADHD. Finally, for the Vocabulary, Picture Concepts, and Matrix Reasoning subtests, females with ADHD had much higher performance than females with ADHD/FASD.

Table 4.11.

Descriptive Statistics for the WISC-IV Subtests

	Females		Males	
Subtest	ADHD (n=42)	ADHD/FASD (n=35)	ADHD (n=105)	ADHD/FASD (n=46)
Coding	8.71 (3.14)	6.82 (3.17)	6.54 (2.68)	6.37 (2.74)
Symbol Search	10.10 (2.28)	8.76 (3.04)	8.34 (2.45)	8.61 (2.67)
Vocabulary	7.59 (2.33)	6.35 (2.73)	6.55 (1.93)	6.59 (2.18)
Picture Concepts	9.98 (3.03)	7.21 (2.96)	8.75 (3.01)	8.41 (3.31)
Matrix Reasoning	9.17 (3.09)	7.50 (3.33)	8.06 (2.94)	7.57 (2.38)

Note. Derived scaled scores range from 1 to 19. Mean scaled score is 10.00 with a standard deviation of 3.00. Standard deviations are shown in parentheses.

Classification and Regression Tree. Classification and Regression Tree (CART) is a statistical method for classification that uses the sequential division of data based on a set of predictor variables to build a decision tree for determining group membership (Davis et al., 2006). The goal of CART is to develop a decision tree that can be used to place individuals in the appropriate category of a categorical response variable (Davis et

al., 2006). Essentially, CART splits up the predictor variable of interest in the most efficient fashion in order to best characterize groupings of the dependent variable. In this study, CART was used to characterize performance on the WISC-IV and Vineland between the four groups. The dependent variables in this study were the scores on the WISC-IV and Vineland and the independent variables were the groups of males and females with ADHD/FASD and males and females with ADHD. In order to discriminate between genders using the CART analysis, two separate CARTs were run. The first CART consisted of only males and the second CART consisted of only females.

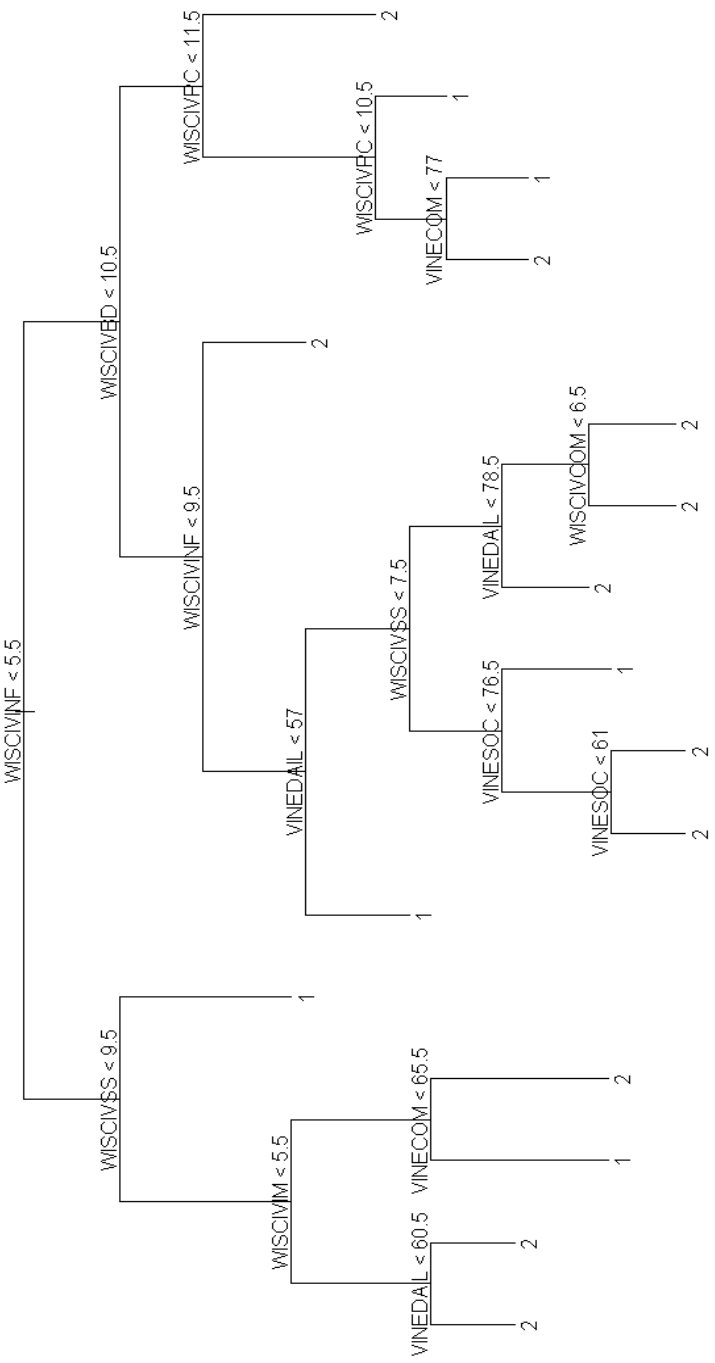
As was a concern with the Vineland data seen previously in Table 4.3 and 4.4, homogeneity of covariance was violated. This assumption is not a concern when it comes to statistical analyses using the CART procedure (Finch, 2011, personal communication). Therefore, both the WISC-IV subtests and the Vineland Composites were used in the CART analyses in this study.

The quality of the decision tree built by CART is judged in two ways: misclassification rates of new cases and the variability of the responses within the final, or terminal, nodes (Davis et al., 2006). A misclassification rate indicates the amount of predictability power the CART analysis has. If a CART analysis has a high misclassification rate the validity of the analysis is low and may not be the best measure to use in the analysis. The variability, or residual mean deviance, is a measure of group heterogeneity among the terminal nodes. A higher variability index indicates greater group heterogeneity in the terminal nodes, which indicates a poorer fit of the analysis to the variables of interest.

In order to include gender into the independent variables in the CART analyses there were two CART analyses performed. The first CART consisted of a sample of only males (151 subjects) and the second CART consisted of only females (77 subjects). By breaking the CART procedure down into two separate analyses there were only two possible options for terminal nodes in each CART and yet gender could also be thought of as a contributing factor to the results. In this sense, there were four independent variables for the CART analyses in total (males with ADHD, males with ADHD/FASD, females with ADHD, and females with ADHD/FASD).

Classification and Regression Tree for Males. Classification and Regression Tree analysis of the first sample discriminating between male patients with ADHD/FASD or ADHD resulted in a hierarchical decision tree with 17 terminal nodes. The residual mean deviance was .677 (91.41/135) and the misclassification rate was .144 (22/152). This indicates that the resulting CART decision tree was correctly able to predict group membership (ADHD/FASD or ADHD) in this instance at an 85.6% rate.

ADHD WITH OR WITHOUT COMORBID FASD



1 = ADHD/FASD
2 = ADHD

Table 4.12.

Classification and Residual Mean Deviance

Subtest	N	RMD	Group	Mean (1)	Mean (2)
WISC-IV Information < 5.5	42	57.84	2	0.45	0.55
WISC-IV Information > 5.5	110	124.80	2	0.25	0.75
WISC-IV Symbol Search < 9.5	33	42.01	2	0.33	0.67
WISC-IV Symbol Search > 9.5*	9	6.28	1	0.89	0.11
WISC-IV Similarities < 5.5	17	12.32	2	0.12	0.88
WISC-IV Similarities > 5.5	16	21.93	1	0.56	0.44
Vineland Daily Living Skills < 60.5*	6	7.64	2	0.33	0.67
Vineland Daily Living Skills > 60.5*	11	0.00	2	0.00	1.00
Vineland Communication < 65.5*	9	6.28	1	0.89	0.11
Vineland Communication > 65.5*	7	5.74	2	0.14	0.86
WISC-IV Block Design < 10.5	77	75.94	2	0.19	0.81
WISC-IV Block Design > 10.5	33	44.25	2	0.39	0.61
WISC-IV Information < 9.5	65	70.23	2	0.23	0.77
WISC-IV Information > 9.5*	12	0.00	2	0.00	1.00
Vineland Daily Living Skills < 57*	6	7.64	1	0.67	0.33
Vineland Daily Living Skills > 57	59	56.76	2	0.19	0.81
WISC-IV Symbol Search < 7.5	25	31.34	2	0.32	0.68
WISC-IV Symbol Search > 7.5	34	20.29	2	0.09	0.91
Vineland Socialization < 76.5	15	11.78	2	0.13	0.87
Vineland Socialization > 76.5	10	13.46	1	0.60	0.40
Vineland Socialization < 61*	6	7.64	2	0.33	0.67
Vineland Socialization > 61*	9	0.00	2	0.00	1.00
Vineland Daily Living Skills < 78.5*	18	0.00	2	0.00	1.00
Vineland Daily Living Skills > 78.5	16	15.44	2	0.19	0.81
WISC-IV Communication < 6.5*	8	0.00	2	0.00	1.00
WISC-IV Communication > 6.5*	8	10.59	2	0.38	0.62
WISC-IV Picture Completion < 11.5	25	34.62	1	0.52	0.48
WISC-IV Picture Completion > 11.5*	8	0.00	2	0.00	1.00
WISC-IV Picture Completion < 10.5	16	21.17	2	0.38	0.62
WISC-IV Picture Completion > 10.5*	9	9.54	1	0.78	0.22
WISC-IV Communication < 77*	8	6.03	2	0.13	0.86
WISC-IV Communication > 77*	8	10.60	1	0.63	0.37

RMD = Residual Mean Deviance
*Terminal Node

From these CART analyses we can see that the primary predictor variable of ADHD/FASD versus ADHD in males is the WISC-IV Information subtest. There were

42 subjects who had a WISC-IV Information subtest score below 5.5 and of these 42 participants, 23 were diagnosed with ADHD. There were 110 subjects who earned a score of greater than 5.5 on the WISC-IV Information subtest and 82 of them were diagnosed with ADHD.

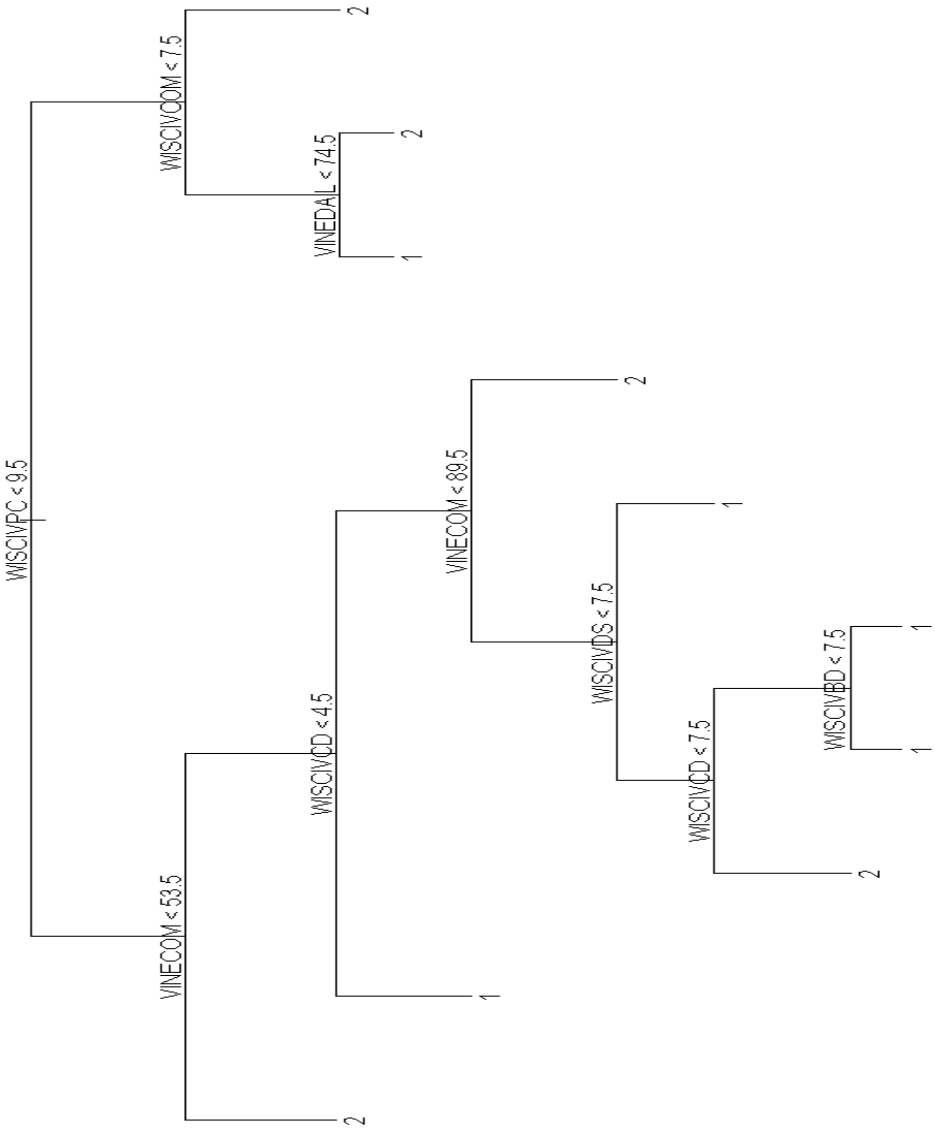
Of the 42 subjects in this study who earned a score of less than 5.5 on the WISC-IV Information subtest there were 33 who also earned less than 9.5 on the WISC-IV Symbol Search subtest. Twenty-two of these 33 subjects were diagnosed with ADHD and eleven were diagnosed with ADHD/FASD. Of the 110 subjects who earned a score of greater than 5.5 on the WISC-IV Information subtest, 77 had a WISC-IV Block Design subtest score of less than 10.5 and the majority (62) of these subjects were diagnosed with ADHD. There were 33 subjects who earned a score of greater than 10.5 on the WISC-IV Block Design subtest and the majority (20) of these 33 subjects were diagnosed with ADHD.

In summary, the results of this first CART show that, of the total 151 subjects used in this CART analysis, 42 had a WISC-IV Information subtest score below 5.5. Of this group, 45% were males diagnosed with ADHD/FASD. This indicates that nearly half (19) of all males with ADHD/FASD (42) in this study had low Information subtest scores. From this information it can be stated that the best single predictor of membership into the ADHD/FASD group was low WISC-IV Information subtest scores. It can also be stated that the combination of low WISC-IV Information subtest scores coupled with WISC-IV Symbol Search scores below 9.5 are considerably good indicators of a male being diagnosed with ADHD rather than ADHD/FASD.

Diagnostically, the information presented in this CART analysis holds great significance based on the evidence that there is an 85.6% chance that a male patient presenting with either ADHD/FASD or ADHD can be accurately differentially diagnosed based on their performance on the WISC-IV and Vineland.

Classification and Regression Tree for Females. Classification and Regression Tree analysis of the second sample discriminating between female patients with ADHD/FASD or ADHD resulted in a hierarchical decision tree with 10 terminal nodes. The residual mean deviance was .373 (26.54/71) and the misclassification rate was .074 (6/81). This indicates that the resulting CART decision tree was correctly able to predict group membership (ADHD/FASD or ADHD) with 92.6% accuracy.

ADHD WITH OR WITHOUT COMORBID FASD



1 = ADHD/FASD
2 = ADHD

Table 4.13.

Classification and Residual Mean Deviance

Subtest	N	RMD	Group	Mean (1)	Mean (2)
WISC-IV Picture Completion < 9.5	51	69.10	1	0.59	0.41
WISC-IV Picture Completion > 9.5	30	30.02	2	0.20	0.80
Vineland Communication < 53.5*	6	0.00	2	0.00	1.00
Vineland Communication > 53.5	45	57.29	1	0.67	0.33
WISC-IV Coding < 4.5*	11	0.00	1	1.00	0.00
WISC-IV Coding > 4.5	34	46.66	1	0.56	0.44
Vineland Communication < 89.5	28	35.16	1	0.68	0.32
Vineland Communication > 89.5	6	0.00	2	0.00	1.00
WISC-IV Digit Span < 7.5	20	27.53	1	0.55	0.45
WISC-IV Digit Span > 7.5*	8	0.00	1	1.00	0.00
WISC-IV Coding < 7.5*	8	6.03	2	0.13	0.87
WISC-IV Coding > 7.5	12	10.81	1	0.83	0.17
WISC-IV Block Design < 7.5*	7	0.00	1	1.00	0.00
WISC-IV Block Design > 7.5*	5	6.73	1	0.60	0.40
WISC-IV Communication < 7.5	13	17.94	2	0.46	0.54
WISC-IV Communication > 7.5*	17	0.00	2	0.00	1.00
Vineland Daily Living Skills < 74.5*	7	8.38	1	0.71	0.29
Vineland Daily Living Skills > 74.5*	6	5.41	2	0.17	0.83

RMD = Residual Mean Deviance
*Terminal Node

From this CART analysis we can see that the primary predictor variable of ADHD/FASD versus ADHD in females was the WISC-IV Picture Completion subtest. There were 51 subjects who had a WISC-IV Picture Completion subtest score below 9.5 and of these 51 subjects, 30 were diagnosed with ADHD/FASD. There were 30 subjects who earned a score of greater than 9.5 on the WISC-IV Picture Completion subtest and the majority (80%) of them were diagnosed with ADHD.

Of the 51 subjects in this study who earned a score of less than 9.5 on the WISC-IV Picture Completion subtest there were 6 who also earned less than 53.5 on the Vineland Communication composite. All of these six subjects were diagnosed with ADHD. Of the 51 subjects who had a score of below 9.5 on the Picture Completion

subtest, 45 subjects also earned a score of greater than 53.5 on the Vineland Communication composite, of which 45 (67%) were diagnosed with ADHD/FASD.

The results of the second CART indicate that WISC-IV Picture Completion subtest scores above 9.5 indicate a high likelihood that a female presenting with either ADHD/FASD or ADHD will end up being diagnosed with ADHD. Picture Completion subtest scores below 9.5 coupled with Vineland Communication subtest scores below 53.5 indicates a greater chance of being diagnosed with ADHD. Finally, Picture Completion subtest scores below 9.5 coupled with Vineland Communication composite scores above 53.5 indicate a greater chance of being diagnosed with ADHD/FASD.

Diagnostically, the information presented in this CART analysis holds a high level of reliability based on the fact that 92.6% of the time a female patient presenting with either ADHD/FASD or ADHD can be accurately differentially diagnosed based on their performance on the WISC-IV and Vineland.

Summary of the Results

The results of this chapter will now be discussed in terms of the six research questions outlined in Chapter 1.

> R_1 What is the profile of composite and subtest cognitive processing scores of the WISC-IV for those children with ADHD/FASD and children with ADHD?

The results obtained from this study indicate that the majority of scores on the WISC-IV subtests were lower for the group of children with ADHD/FASD than the sample of children with ADHD. An examination of individual subtests indicates that females with ADHD had the highest subtest scores for nine of eleven subtests. Children

with ADHD were in the Average range for Block Design, Picture Concepts, Matrix Reasoning, and Symbol Search. Females with ADHD/FASD were in the Average range for Symbol Search while males with ADHD/FASD were in the Average range for Block Design, Picture Concepts, and Symbol Search. Females with ADHD performed the poorest on Digit Span, Similarities, and Information. Females with ADHD/FASD performed the poorest on Comprehension, Vocabulary, and Information. Males with ADHD performed the lowest on Coding, Vocabulary, and Digit Span. Finally, males with ADHD/FASD performed the lowest on Coding, Digit Span, and Comprehension.

R_2 Is there a significant difference on overall cognitive ability between those children with ADHD/FASD and children with ADHD?

Overall omnibus MANOVA results indicated that there was a significant difference on the WISC-IV subtests for diagnosis, gender, and the interaction of diagnosis by gender.

R_3 Are there significant differences on cognitive skills measures between those children with ADHD/FASD and children with ADHD?

The results from the WISC-IV MANOVA in Table 4.7 indicated that there were significant group differences between those with ADHD and those with ADHD/FASD on the WISC-IV Picture Concepts, Coding, Matrix Reasoning, Comprehension, and Information subtests. There were significant gender differences on the Block Design, Coding, and Symbol Search subtests. Finally, there were significant interaction effects of

diagnosis by gender on the Picture Concepts, Coding, Vocabulary, and Symbol Search subtests.

R_4 What is the profile of adaptive skills composite scores of the Vineland for those children with ADHD/FASD and children with ADHD?

A review of the Vineland composites shows that the groups with ADHD/FASD had lower scores on all measures of adaptive functioning. The male and female groups with ADHD/FASD had Adaptive Behavior Composite average scores in the Very Low range which is considered to be in the Mildly Mentally Retarded range based on normal curve properties (scores below 70 are considered to be in the Mildly Mentally Retarded range). Males with ADHD were also in this Mildly Mentally Retarded range but their average scores were slightly higher, with an average overall composite of 68.39. Females with ADHD were the only group whose overall Adaptive Skills composite scores were above the Mildly Mentally Retarded range with an average of 72.12

R_5Are there significant differences on adaptive skills measures between those children with ADHD/FASD and children with ADHD?

The fifth question is not able to be reliably answered considering that the MANOVA for the Vineland was unable to be interpreted. However, in order to answer this question the ANOVA results can be referenced in which the Vineland Overall Adaptive Skills composite scores were analyzed. Overall Adaptive Composite scores for the ADHD/FASD and ADHD groups were significantly different ($F = 6.48$, $p = .01$)

indicating that children with ADHD/FASD perform significantly worse on overall adaptive skills than children with ADHD.

R_6 Which of the cognitive and adaptive skills composites contribute the greatest to the differences in functioning between those children with ADHD/FASD and children with ADHD?

According to the results of the DA, the subtests that contributed most greatly to the differences in functioning between the groups with ADHD/FASD and the groups with ADHD was the WISC-IV Coding subtest. Males with ADHD/FASD scored significantly lower than females with ADHD on this subtest and this subtest was able to discriminate between the four groups in this study better than any other WISC-IV subtest. Following the WISC-IV Coding subtest the WISC-IV Symbol Search, WISC-IV Vocabulary, WISC-IV Picture Concepts, and WISC-IV Matrix Reasoning subtests were able to significantly predict group membership between the ADHD/FASD groups and the ADHD/FASD groups. The Vineland was unable to be used for this analysis due to the violation of homogeneity of covariance.

R_7 What are the specific cognitive and adaptive skills deficits that most likely classify a diagnosis of ADHD/FASD or ADHD?

According to the results of the CART analyses the best way to predict group membership into either the ADHD/FASD group or ADHD group for males was through the primary predictor variable of the WISC-IV Information subtest. The CART analysis found that those children who scored below a 5.5 on this subtest belonged to the ADHD

group with 55% accuracy. The WISC-IV Information, Symbol Search, Block Design, Similarities, and Picture Completion subtests along with the Vineland Communication and Socialization composites were able to accurately predict group membership into either the ADHD/FASD or ADHD group with 85.6% accuracy.

The best predictor of group membership for females was the WISC-IV Picture Completion subtest. Females with a Picture Completion score above 9.5 belonged to the ADHD group with 80% accuracy. The combination of WISC-IV Picture Completion, Comprehension, Coding, Digit Span, and Block Design along with the Vineland Daily Living Skills and Communication composites were able to accurately predict group membership 92.6% of the time.

R_8 Does ethnicity, prescription medication, or gender significantly account for the differences in functioning between the two diagnostic groups?

Initial examinations into prescription medication and race indicated that neither of these factors contributed to a significant difference between diagnostic groups in cognitive and adaptive skills. Gender, however, did show a significant effect for perceptual reasoning and processing speed abilities with females outperforming males in these areas.

Conclusions

In summary, the results of this study indicated that there were significant cognitive processing and adaptive skills deficits between the ADHD/FASD groups and the ADHD groups. Furthermore, the ADHD female group performed significantly greater on more cognitive and adaptive skills measures than any of the other three groups. These

results suggest that the neurofunctional deficits seen in children with ADHD/FASD outweigh those seen in the ADHD population, especially for females. In other words, being exposed to alcohol in utero puts a child at a far greater risk of having significant impairment in cognitive and adaptive skills functioning.

A review of the MANOVA indicates that cognitive ability as measured by the WISC-IV subtests was significantly different between the ADHD and ADHD/FASD groups on the WISC-IV Picture Concepts, Coding, Matrix Reasoning, Comprehension, and Information subtests. Likewise, overall levels of adaptive skills as measured by the Vineland Adaptive Behavior Composite were significantly higher for the ADHD group than the ADHD/FASD group. This supports the view that those children exposed to alcohol in utero are more likely to have diminished cognitive and adaptive skills possibly secondary to neurofunctional deficits. Daily living skills deficits seen in children with ADHD/FASD may be due to the significantly greater verbal, nonverbal, and working memory skills deficits found in children with ADHD/FASD in comparison with children who have ADHD.

Results from the Discriminant Factor Analysis indicated that the one assessment that is able to most greatly discriminate between the ADHD/FASD and ADHD groups is the WISC-IV Coding subtest. Children with ADHD/FASD scored, on average, significantly lower than children with ADHD on the Coding, Symbol Search, Vocabulary, Picture Concepts, and Matrix Reasoning subtests, so much so, in fact, that these subtests are able to significantly predict group membership into these diagnostic classifications. After looking at the average scores on these measures for each of the

groups it is able to be assumed that children with ADHD/FASD have far greater processing speed, verbal, and nonverbal skills deficits than children with ADHD.

Other measures that were able to reliably discriminate between the ADHD/FASD groups and the ADHD groups, according to the CART analyses, included verbal measures of cognitive ability (WISC-IV Information, WISC-IV Comprehension) as well as communication skills (Vineland Communication Composite), processing speed (WISC-IV Symbol Search), and nonverbal measures of cognitive ability (WISC-IV Block Design). These results suggest that children with ADHD/FASD can reliably be separated from children with ADHD by their verbal, nonverbal, communication, and processing speed deficits.

Chapter 5

Discussion

This chapter is divided into five sections: (1) summary of the present study, (2), discussion and implications of the findings, (3), limitations and delimitations of the study, (4), directions for future research, and (5) conclusions.

Summary of the Study

The purpose of the present study was to investigate the differences in cognitive and adaptive skills between males and females with comorbid ADHD/FASD and those with ADHD using the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2003) and the *Vineland Adaptive Behavior System* (Sparrow, Balla, & Cicchetti, 1984). This study also investigated which elements of these tests best discriminate between these four groups and what is the most useful combination of measures to assist in diagnostic decision-making between these groups. The data from this study were collected from 105 males with ADHD (mean age = 10 years, 1 month; SD = 2 years, 11 months), 42 females with ADHD (mean age = 10 years, 1 month; SD = 3 years, 5 months), 46 males with ADHD/FASD (mean age = 10 years, 6 months; SD = 2 years, 10 months), and 35 females with ADHD/FASD (mean age = 9 years, 2 months; SD = 2 years, 6 months). All of the patients in this study were administered the WISC-

IV and Vineland as part of a neuropsychological evaluation. Data for this study were collected from an archival data set retrospectively after neuropsychological evaluations had been completed.

To assess overall group differences on the WISC-IV and Vineland, two separate Multivariate Analyses of Variances (MANOVAs) were conducted. In order for a MANOVA to be interpreted with confidence the assumptions of MANOVA must first be met. In this study the assumption of homogeneity of covariance was not met for the Vineland MANOVA. Therefore, the results of the Vineland MANOVA were not analyzed; however, a Univariate Analysis of Variance (ANOVA) was conducted on the Vineland Overall Adaptive Behavior Composite which is an amalgamation of each of the composites of the Vineland. This ANOVA was able to be interpreted as it met all of the assumptions for reliable interpretation.

After the MANOVA and ANOVA were conducted, a follow-up Discriminant Analysis (DA) was run to more fully understand which of the dependent variables on the WISC-IV were accounting for the most overall difference between the clinical groups. A DA identifies and describes the discriminant function variates of a set of variables and is useful as a follow-up test to a MANOVA as a means of seeing how these variates allow groups of cases to be discriminated (Field, 2005). Finally, a Classification and Regression Tree (CART) analysis was conducted to represent the best predictors of group membership into the ADHD or ADHD/FASD groups in a flowchart.

WISC-IV: Multivariate Analysis of Variance. Overall Multivariate test statistics indicated that there was a significant difference between diagnostic groups [$F(1, 227) = 2.55$; $p < .01$], gender [$F(1, 227) = 2.82$; $p < .01$], and there was a significant

interaction effect between diagnostic groups and gender [F (3, 227) = 2.23; p = .01] on the WISC-IV subtests. Analyzing individual univariate ANOVAs from a MANOVA is not an optimal procedure when investigating group differences on outcome variables; however, these individual ANOVA test statistics do help provide further information regarding individual performance on each outcome variable. In light of this, the following is a discussion regarding these individual ANOVAs that were generated from the larger MANOVA for the WISC-IV subtests.

WISC-IV MANOVA Group Effects. There was a significant difference between the ADHD and ADHD/FASD groups on the WISC-IV Picture Concepts and Matrix Reasoning subtests. These subtests assess nonverbal information processing and concept formation which are primarily functions of the frontal and parietal lobes (Kolb & Whishaw, 2009). These results raise the possibility that more dysfunction may be present in the prefrontal lobes, involved in executive functioning (Wahlstrom and Luciana, 2011), and the parietal lobes, involved in visual information processing (Sowell et al., 2001) in children with ADHD/FASD in comparison with children who have ADHD.

There was also a significant difference in the performance of children with ADHD/FASD and children with ADHD on the WISC-IV Coding subtest with children with ADHD/FASD performing significantly lower. The Coding subtest measures incidental learning, attention, and nonverbal information processing. These abilities are mainly navigated by the frontal lobes, hippocampus, and cerebellum (Eslinger, 2011; Lezak et al., 2004). This indicates that the frontal lobes, involved in executive functioning; the hippocampus, involved in memory; and the cerebellum, critical during

working memory and attention tasks, may potentially be more highly impacted in children with ADHD/FASD than those with ADHD.

Performance on the WISC-IV Comprehension and Information subtests were significantly more impaired for children with ADHD/FASD than those with ADHD. These subtests involve the use of verbal reasoning and crystallized knowledge which are functions primarily driven by the frontal lobes, hippocampus, and the dominant temporal lobe (Kolb and Whishaw, 2009) which is also the language center of the brain.

In summary, the patients in this study with ADHD/FASD performed significantly poorer than children with ADHD on tasks measuring verbal and nonverbal information processing, attention, and executive functioning. These results support previous studies indicating significant impairment for children with FASD in cortical areas critical for navigating these types of tasks such as the left frontal lobe (Archibald et al., 2001; Sowell et al., 2001), overall frontal lobe (Fryer et al., 2009), hippocampus (Astley et al., 2009; Autti-Ramo et al., 2002; Bhatara et al., 2002; Wacha & Obrzut, 2007), temporal lobe (Sowell et al., 2001; Vaurio et al., 2008), parietal lobe (Riikonen et al., 1999; Sowell et al., 2008a, 2008b), and cerebellum (Archibald et al., 2001; Mattson et al., 1992, 1994, 1996; Wacha & Obrzut, 2007).

ADHD WITH OR WITHOUT COMORBID FASD

The following table summarizes the findings of the effect of diagnosis of either ADHD/FASD or ADHD on the WISC-IV:

Table 5.1.

WISC-IV MANOVA Group Effect Results and Neurological Implications

WISC-IV Subtest	Results	Neurological Correlates
Picture Concepts	Significant ($p < .01$) ADHD = 9.11 ADHD/FASD = 7.90	Those with ADHD/FASD may have more parietal and frontal lobe impairment than those with ADHD.
Coding	Significant ($p < .05$) ADHD = 7.17 ADHD/FASD = 6.56	Those with ADHD/FASD may potentially have more frontal lobe, cerebellar, and hippocampal impairment than those with ADHD only.
Matrix Reasoning	Significant ($p < .01$) ADHD = 8.38 ADHD/FASD = 7.54	Those with ADHD/FASD may have more parietal and frontal lobe impairment than those with ADHD.
Comprehension	Significant ($p < .01$) ADHD = 7.32 ADHD/FASD = 6.14	Those with ADHD/FASD could possibly have more impairment in the frontal lobes, dominant temporal lobe, and hippocampus than those with ADHD.
Information	Significant ($p = .01$) ADHD = 7.45 ADHD/FASD = 6.50	Those with ADHD/FASD may have more frontal lobe and hippocampal impairment than those with ADHD.

WISC-IV MANOVA gender effects. There was a significant overall gender effect ($p < .05$) on the WISC-IV MANOVA. Males performed significantly better than females on the Block Design subtest ($p < .05$) and females performed better than males on the Coding ($p < .01$) and Symbol Search ($p < .01$) subtests. These results suggest that males with ADHD/FASD or ADHD out-perform females with ADHD/FASD or ADHD on tasks requiring nonverbal information processing and concept formation which is

primarily functions of the frontal and parietal lobes (Wahlstrom and Luciana, 2011). These results also suggest that females with ADHD/FASD or ADHD out-perform males with ADHD/FASD or ADHD on measures of short-term memory, attention, and nonverbal information processing. These abilities are mainly regulated by the frontal lobes, cerebellum, hippocampus, and parietal lobes (Allen et al., 2011; Eslinger, 2011; Lezak et al., 2004).

The following table summarizes the findings of the effect of gender on the WISC-IV:

Table 5.2.

WISC-IV MANOVA Gender Effect Results and Neurological Implications

WISC-IV Subtest	Results	Neurological Correlates
Block Design	Significant ($p < .05$) Females = 7.72 Males = 8.52	Females with either ADHD/FASD or ADHD may have more parietal and frontal lobe impairment than males with either ADHD/FASD or ADHD.
Coding	Significant ($p < .01$) Females = 7.85 Males = 6.49	Males with either ADHD/FASD or ADHD may have more frontal lobe, cerebellar, and hippocampal impairment than females with either ADHD/FASD or ADHD.
Symbol Search	Significant ($p < .01$) Females = 9.49 Males = 8.42	Males with either ADHD/FASD or ADHD could potentially have more frontal lobe, cerebellar, and hippocampal impairment than females with either ADHD/FASD or ADHD.

WISC-IV MANOVA interaction effects. An interaction occurred in this study between the four groups. An interaction occurs when there is a significant combined effect of two or more predictor variables on an outcome variable (Field, 2005). Given that

there are four groups (predictor variables) in this study it is not known which of these groups were contributing to the overall interaction effect on each of the WISC-IV subtests (outcome variables). However, the greatest discrepancies were seen for females with ADHD performing better than females with ADHD/FASD on Picture Concepts and Vocabulary and females with ADHD performing better than males with ADHD/FASD on Coding and Symbol Search.

These results suggest that females with ADHD out-perform females with ADHD/FASD on tasks involving nonverbal information processing and concept formation which are abilities largely regulated by the parietal and frontal lobes (Wahlstrom and Luciana, 2011). These results also suggest that females with ADHD performed significantly better than males with ADHD/FASD on tasks involving short-term memory, attention, and nonverbal information processing which are functions largely driven by the frontal lobes, cerebellum, parietal lobes, and hippocampus (Allen et al., 2011; Eslinger, 2011; Lezak et al., 2004). Finally, females with ADHD performed significantly better than females with ADHD/FASD on crystallized knowledge which is largely driven by hippocampal and frontal lobe functioning (Kolb and Whishaw, 2009; Wahlstrom & Luciana, 2011). The following table summarizes the findings of the interaction effects on the WISC-IV subtests:

Table 5.3.

WISC-IV MANOVA Gender Effect Results and Neurological Implications

WISC-IV Subtest	Results	Neurological Correlates
Picture Concepts	Significant ($p < .01$) ADHD Fem = 9.98 ADHD/FASD Fem = 7.72	Females with ADHD/FASD may have less frontal and parietal lobe impairment than females with ADHD/FASD.
Coding	Significant ($p < .05$) ADHD Fem = 8.71 ADHD/FASD Males = 6.37	Females with ADHD may have less frontal lobe, cerebellar, and hippocampal impairment than males with ADHD/FASD.
Vocabulary	Significant ($p < .05$) ADHD Fem = 7.59 ADHD/FASD Fem = 6.35	Females with ADHD could potentially have less frontal lobe and hippocampal impairment than females with ADHD/FASD.
Symbol Search	Significant ($p < .05$) ADHD Fem = 10.10 ADHD/FASD Males = 8.61	Females with ADHD may have less frontal lobe, cerebellar, and hippocampal impairment than males with ADHD/FASD.

Vineland Multivariate Analysis of Variance. Overall Multivariate test statistics for the Vineland could not be reliably interpreted due to a violation of homogeneity of covariance. An analysis of the descriptive statistics for the Vineland indicated that communication, daily living skills, and socialization skills were all much lower in each of the groups in this study than would be expected based upon the cognitive abilities of these samples. Descriptive statistics for the WISC-IV showed that those children with ADHD and ADHD/FASD had largely below average cognitive abilities while the adaptive skills of these samples were in the impaired range, nearly two standard deviations below the mean in all areas investigated.

Vineland Overall Adaptive Behaviors Composite Univariate Analysis of Variance. An effect of diagnosis was found on the Vineland Overall Adaptive Behavior

Composite in that children with ADHD were rated to have significantly better developed adaptive skills than those with ADHD/FASD. Overall adaptive skills are an integration of communication, daily living skills, and social skills and therefore are an indicator of myriad neurological functions. The significant difference on overall adaptive skills between those children with ADHD and ADHD/FASD provides further evidence that overall neurological functioning, indicated by performance practical skills of daily living, may be more impaired in children with ADHD/FASD than children with ADHD.

WISC-IV Discriminant Analysis. A follow-up DA was conducted in order to investigate which of the WISC-IV subtests were most effective at predicting group membership into the ADHD or ADHD/FASD groups. The results of the DA indicated that the best WISC-IV subtests for predicting group membership into the ADHD or ADHD/FASD groups were the Coding, Symbol Search, Vocabulary, Picture Concepts, and Matrix Reasoning subtests. These results suggest that the best way to discriminate between the four groups in this study include measures of short-term memory, attention, nonverbal information processing, crystallized knowledge, nonverbal information processing and nonverbal concept formation. The following table breaks down each subtest and neurological areas of importance for these subtests.

Table 5.4.

Discriminant Analysis Subtests, Function, and Neurological Implications

Subtest	Subtest Function	Neurological Correlates
Coding and Symbol Search	Short-term memory, attention, and nonverbal information processing	Children with ADHD/FASD may have more impairment in the hippocampus, frontal lobes, cerebellum, and parietal lobes than children with ADHD.
Vocabulary	Crystallized knowledge	Children with ADHD/FASD may have more impairment in the frontal lobes and hippocampus than children with ADHD.
Picture Concepts and Matrix Reasoning	Nonverbal information processing and concept formation	Children with ADHD/FASD may have more impaired frontal and parietal lobes than children with ADHD.

Classification and Regression Tree. A CART analysis was used in order to develop a decision tree that could be used to place individuals in the appropriate category of a categorical response variable (Davis et al., 2006), in this case, ADHD or ADHD/FASD. A CART analysis essentially uses information similar to a DA in order to most effectively characterize how independent variables can be grouped based upon performance on the dependent variables. The independent variables in this analysis were the diagnostic groups of children with ADHD/FASD and children with ADHD. The dependent variables were each of the WISC-IV subtest and the Vineland composites.

In order to include gender as a response variable two separate CART analyses were conducted, one for males and one for females. Results from the first CART investigating males indicated that the best predictor variable of group membership (ADHD or ADHD/FASD) for males was the WISC-IV Information subtest due to children with ADHD having a greater chance of scoring less than a standard score of 5.5

on this assessment. However, this CART also indicated that 75% of those with ADHD scored above a 5.5 on the Information subtest while only 25% of those with ADHD/FASD scored above a 5.5 on the Information subtest. This indicates that the best way to predict group membership using the WISC-IV into the ADHD/FASD group is to have WISC-IV Information scores below 5.5. Overall, the combination of WISC-IV Information, Symbol Search, Similarities, Block Design, Information, Comprehension, Picture Concepts, and Vineland Daily Living Skills, Communication, and Socialization resulted in a correct diagnosis of either ADHD or ADHD/FASD with 85.6% accuracy for males.

Results from the CART analysis of females indicated that the best predictor variable for inclusion into either the ADHD or ADHD/FASD group was the WISC-IV Picture Concepts subtest. Only 20% of the children who scored above 9.5 on the WISC-IV Picture Concepts subtest were diagnosed with ADHD/FASD. Overall, the combination of WISC-IV Picture Concepts, Coding, Digit Span, Block Design, Comprehension, and Vineland Communication and Daily Living Skills resulted in a 92.6% chance for correct diagnosis based on these subtests alone.

Discussion and Implications

The results of the present study indicated that there are significantly greater verbal, perceptual reasoning, working memory, processing speed, and adaptive skills deficits in children with ADHD/FASD than those with ADHD. This suggests that there may be neurofunctional differences between children with ADHD and children with ADHD/FASD. The more significant level of impairment seen in children with ADHD/FASD may exist due to the neuroanatomical dysfunction that has been

documented for children with FASD. Verbal difficulty in children with FASD may be due to left frontal lobe (Archibald et al., 2001; Sowell et al., 2001), temporal lobe (Sowell et al., 2001), parietal lobe (Riikonen et al., 1999), cerebellum, (Mattson et al., 1996, Archibald et al., 2001, Mattson et al., 1992, Mattson et al., 1994), corpus callosum, (Riley & McGee, 2005), hippocampus (Wacha & Obrzut, 2007), and hypothalamus (Gabriel et al., 1998; Druse, 1992; Hawthorne, 1992) impairment that has been documented in this population.

Deficits in perceptual reasoning have not consistently been noted in children with ADHD (Barkley, 2006) and results from the current investigation support the lack of perceptual reasoning deficits as the sample of children with ADHD in this study had Average scores on the WISC-IV Picture Concepts, Block Design, and Matrix Reasoning subtests. However, results from the current study indicate that children with FASD had impairment in perceptual reasoning and it has been hypothesized that these deficits in perceptual reasoning in children with FASD may be due to impairment in the temporal and parietal lobes (Sowell et al., 2001), especially in the right hemisphere, as the non-dominant parietal lobe has been shown to play an important role in visual information processing.

Working memory deficits have been historically documented in children with ADHD as well as those with FASD. The current study indicates that children with ADHD/FASD have greater impairment than those with ADHD in measures of working memory. Studies investigating working memory in children with FASD have shown substantial deficits (e.g., Kodituwakku et al., 1995; O'Hare et al., 2005; Rasmussen, 2005). These deficits may be due to the large-scale dysfunction in the areas of the brain

responsible for working memory such as the prefrontal cortex which are seated in the frontal lobes, temporal lobes (Vaurio et al., 2008b), hippocampus (Autti-Ramo et al., 2000; Bhatara et al., 2002), basal ganglia (Mattson et al., 1992), thalamus (Henry et al., 2007; Mattson et al., 1994), and hypothalamus (Gabriel et al., 1998; Druse, 1992; Hawthorne, 1992).

Processing speed deficits have been noted as hallmark symptomatology in children with ADHD (e.g. Heaton et al., 1993; Willcutt, 2010). Children with FASD have also been found to have significant deficits in processing speed (Carmichael-Olson et al, 1998; Rasmussen, 2005). Deficits in processing speed for children with ADHD and children with FASD may be due to impairment in the cerebellum, frontal lobes, corpus callosum, thalamus, and hypothalamus which are all directly or indirectly involved in processing speed. Although impairment in processing speed in children with ADHD has been noted empirically it is not as significant as the processing speed deficits found in children with ADHD/FASD according to the present study. This may be due to the high level of neuroanatomical dysfunction noted in children with FASD in the frontal lobes (Archibald et al., 2001; Sowell et al., 2001), cerebellum (Mattson et al., 1996, Archibald et al., 2001, Mattson et al., 1992, Mattson et al., 1994), corpus callosum (Riley & McGee, 2005), thalamus (Henry et al., 2007; Mattson et al., 1994), and hypothalamus (Gabriel et al., 1998; Druse, 1992; Hawthorne, 1992).

Overall adaptive skills and daily living skills were found to be significantly lower in children with ADHD/FASD compared to children with ADHD in this study. Children with FASD have been shown to have difficulty with communication (Wacha & Obrzut, 2007), socialization (Crocker et al., 2009; McGee et al., 2008), and motor skills

(O'Leary, 2004). Furthermore, Rasmussen and colleagues (2007) found that children with FASD had difficulty with initiation of tasks, and generating ideas, responses, and problem-solving strategies, which are all critical in daily living skills. The significant deficits in adaptive skills in children with FASD may be due to the significant cognitive skills deficits seen in this population which may be secondary to gross neuroanatomical dysfunction.

Considering that there are significant differences seen in the cognitive and adaptive skills profiles between children with ADHD and children with ADHD/FASD, the types and intensity of psychopharmacological and therapeutic interventions for these two groups may vary. It has been shown that children with FASD are often overly sensitive to the side effects of medication (O'Malley & Nanson, 2002). Therefore, being able to differentiate between children with ADHD and children with ADHD/FASD may be critical. Also, when it comes to psychopharmacological intervention, it may be necessary to more closely monitor children with FASD who are on medication or perhaps find other methods of treatment.

It has been shown that children with ADHD/FASD have different reactions to psychostimulant medication than those with ADHD. Research has shown that children with FASD are often overly sensitive to the effects and side effects of medication due to the unique neurochemical and structural changes in the CNS (O'Malley & Nanson, 2002). In one study in 1996, children with ADHD/FASD were given methylphenidate to reduce hyperactivity, impulsivity, and inattentiveness and only 47% had a successful response (Streissguth, 1996). Furthermore, O'Malley and colleagues (2000) found only a 22% response rate to methylphenidate in children with ADHD/FASD. However, in

comparison, Schachter and colleagues (2001) conducted a meta-analysis in which they found that 70% of children with ADHD improved after methylphenidate treatment. In contrast, O'Malley and colleagues (2000) found that 79% of children with ADHD/FASD improved with dextroamphetamine (Dexedrine). Therefore, differentiating between ADHD/FASD and ADHD may improve psychopharmacological interventions research shows that proper medication benefits up to 79% of children with properly diagnosed ADHD in treating the major symptoms of inattention, hyperactivity, and impulsivity (Greenhill et al., 2002).

The current study indicated that children with ADHD/FASD significantly struggled on measures of verbal ability. There are many types of interventions that can be implemented for children with FASD based upon these verbal ability deficits. Some specific strategies that can be implemented for children with language skills deficits such as those seen in children with FASD include, (1) using visual cues and verbal aids, (2) using concrete language, and (3) using visual, tactile, and kinesthetic instructional strategies (Bernstein-Clarren et al., 2004).

The children in this study with ADHD/FASD were shown to have significant difficulty with measures of short-term memory and working memory. These difficulties with memory may be exacerbated in the academic environment where instruction is taking place and academic tasks are being assigned frequently. Some examples of strategies that can be used to help children with FASD with memory difficulties include, (1) breaking down large amounts of directions into more manageable chunks, (2) writing down verbal instructions, (3) using language that is concrete and familiar, and (4)

providing visual structural cues frequently such as having directions and schedules written on posters throughout the room.

The current study indicated that children with ADHD/FASD have significant difficulty with tasks requiring focused and sustained attention. Some examples of ways in which attentional difficulties may manifest themselves in children with FASD in the classroom include missing instructions, being easily distracted, having difficulty engaging in two tasks simultaneously (listening to the teacher and taking notes), and looking attentive but having trouble understanding and responding appropriately (Bernstein-Clarren et al., 2004). Some ways in which attention difficulties can be guarded against in children with FASD include creating work areas that are free from distraction, keeping group sizes small, limiting the number of instructions given at one time, allowing short breaks during periods of extended instruction, and having students with attention problems sit close to the teacher in order to see and hear directions and lessons with greater accuracy.

Adaptive skills are those behaviors that allow for children to successfully adapt to their environment. According to the current study, children with FASD have significantly low scores in overall adaptive skills than children with ADHD. This means that children with FASD have significant deficits in communication, daily living skills, and social skills. Deficits in adaptive skills may manifest in many ways including children acting younger than their chronological age, having no friends their own age, having problems with time management, and being naïve and gullible (Bernstein-Clarren et al., 2004). Interventions for children with adaptive skills deficits such as those children with ADHD/FASD in this study include providing extra supervision, creating a daily planner

that details the student's schedule to help them with time management, providing counseling services to help teach coping skills, and providing children with social skills instruction.

The current study helps further the field of neuropsychology by detailing the neuropsychological profile of children with ADHD/FASD. The current study indicates that children with ADHD/FASD differ from children with ADHD cognitively and adaptively with significant differences between the groups in executive functioning, short-term memory, working memory, verbal ability, and perceptual reasoning. This information helps to further the field of neuropsychology given that the majority (95%, Fryer et al., 2007) of children with FASD also have ADHD; however, the physiological indications of intrauterine alcohol exposure (i.e., flat midface, flat philtrum, palpebral fissures, etc.) may not always be present in children with FASD. Therefore, when a child presents to a neuropsychology practitioner it may be difficult to distinguish whether a child with ADHD may also have comorbid FASD. However, the current study helps to differentiate between these two groups, and, based on the CART analysis, may be able to distinguish between these two groups with 85.6% accuracy for males and 92.6% accuracy for females using the WISC-IV and Vineland. Based on the results of this study diagnostic decisions and interventions may be made more easily for neuropsychologists when working with children who have ADHD with or without comorbid FASD.

The current study also helps improve the understanding of the cognitive and adaptive skills strengths and weaknesses that children with ADHD/FASD have which may help improve instruction and interventions in the classroom environment. Investigating the strengths and weaknesses of children with ADHD/FASD may help

school psychologists work with these children. School systems often request that school psychologists take the lead in developing appropriate interventions and accommodations for children with neurodevelopmental disorders (Davis & Phelps, 2008); therefore, an increased understanding of neurodevelopmental disorders such as FASD is essential. School psychologists, to serve as effective advocates for children, should focus on outcomes, employ more preventative techniques, utilize empirically supported interventions, and take an active role in initiating changes in their schools and the communities (Davis, 2001). With the results from this study, school psychologists should be able to more easily recognize the patterns of cognitive and adaptive skills strengths and weaknesses of children with ADHD/FASD and help support the educational needs of these children.

Limitations and Delimitations of the Study

There were several limitations inherent in the current study. The first is that the impact of intrauterine alcohol exposure may have been confounded by other drug use by children's mothers during pregnancy as this information was unknown for the samples investigated in this study. This is a threat to internal validity as it has been shown that up to half of women who use illicit drugs during pregnancy also smoke cigarettes and drink alcohol (Ebrahim & Groerer, 2003). Therefore, the deleterious impact on cognitive and adaptive skills of children with ADHD/FASD may be partly explained by other teratogen exposure during pregnancy and not simply due to intrauterine alcohol exposure.

Second, environmental factors such as home environment or a synergy between prenatal alcohol exposure and environmental factors may play a role (Thomas et al., 1998) in the negatively affected cognitive and adaptive skills of children with

ADHD/FASD. This type of information is difficult to quantify and investigate in large sample studies and environmental factors were not investigated in this study. Third, the data from the participants in this study were gathered from a rural/suburban Midwestern area. Therefore, the generalizability of this study may be limited. Fourth, the data that were collected from this study may have been subject to record-keeping and assessment scoring procedural errors. There were two levels of data encryption used for this study and multiple graduate student researchers transcribed this data. Therefore, some of the data may have been at a higher level of possible data entry error. Along these lines, assessments conducted on children in this study were subject to selective data gathering procedures. Due to these procedures, data such as who the caregivers were at the time of assessment were not gathered on every participant. Finally, many of the children in this study with ADHD/FASD or ADHD had comorbid conditions such as anxiety, depression, post-traumatic stress disorder, and organic encephalopathy. These conditions were not controlled for and may have played a part in the cognitive and adaptive skills deficits of the samples seen in this study. For instance, children with anxiety disorders may evidence difficulty with cognitive, academic, and executive functions (Viezel, 2011); the performance of children with depressive symptomatology may be impaired by the presence of dysphoric mood, agitation, poor attitude toward achievement, and low energy (Garcia-Barerra, 2011). Children with post-traumatic stress disorder may have impaired functioning secondary to symptoms similar to that of children with anxiety disorders (i.e., cognitive, academic, and executive functioning difficulty) due to heightened arousal and anxiety.

The sample sizes used in the current investigation was the greatest delimitation of the study. The current study investigated the cognitive and adaptive skills of 147 children with ADHD and 81 children with ADHD/FASD. Most studies involving children with FASD have sample sizes less than 81. National surveillance studies (Elliott et al., 2008) investigating children with FASD even have difficulty getting more than 100 patients in their study; the national surveillance study conducted by Elliot and colleagues (2008) was only able to garner 92 children with FAS. Other studies generally have much more conservative sample sizes such as Burden and colleagues (2009; 13), Meintjes and colleagues (2010; 33), Rasmussen and colleagues (2007; 64), Doig and colleagues (2008; 27), and Herman and colleagues (2008; 36). Generalizability may have been negatively affected by the geographical restrictions placed on the data; however, given the large sample size for the ADHD/FASD as well as the ADHD samples, this generalizability was improved. Also, the assessments used in this study including the WISC-IV and Vineland are largely considered the "gold standards" in cognitive and adaptive skills assessment, respectively. Therefore, the data presented in this study is well-representative of highly respected measures of cognitive and adaptive skills functioning. Third, the diagnostic procedures used in this study were valid and reliable based on the same neuropsychologist making the ADHD diagnoses and the dual role of this same neuropsychologist as well as a physician specializing in medical genetics and pediatric developmental disorders used in the diagnosis of all children with an FASD diagnosis. These two diagnosticians used a comprehensive physiological and neuropsychological evaluation following the standards outlined in the 4-Digit Diagnostic Code (Astley & Clarren, 1999) in order to diagnose children with FASD. Due to the strengths of the

diagnostic procedures used for the participants in this study, the validity and reliability of the diagnoses of the ADHD/FASD and ADHD samples are high. Finally, all children in this study diagnosed with ADHD were of the ADHD, Combined Type. This minimizes the doubts that have been raised regarding the diagnostic heterogeneity between the ADHD, Predominantly Hyperactive-Impulsive Type and ADHD, Predominantly Inattentive Type.

Directions for Future Research

The directions for future research are designed to improve on any limitations in the current study and draw upon areas of the greatest need in the study of children with FASD. First, there is inherent difficulty in ascribing the deleterious effects of alcohol exposure as the sole means of cognitive and adaptive skills deficits in children with FASD when other teratogens such as cigarette smoke or illicit drugs may be culprits in these deficits as well. It may be necessary when conducting research in this area in the future to take copious notes on the affected individual's mother's drug use during pregnancy, focusing in particular on any possible teratogen use beyond alcohol. Second, studies looking at the effects of intrauterine alcohol exposure in the future may want to take an ecological approach to the contributing factors that may play a role in cognitive and adaptive skills deficits such as limited exposure to academically stimulating material at a young age, nutrition, sleep patterns, and parenting styles. In order to reduce the possibility for errors to be made in encryption when collecting and entering data, studies in this area should incorporate more reliable data collection procedures such as using fewer researchers and following strict data collection protocols by all researchers. Finally, in order to reduce the possible lack of generalizability, it may be necessary in

future studies to collect data from a more geographically disparate sample and increasing the sample size of the groups being studied. Finally, many of the children in this study were diagnosed with comorbid conditions. The comorbid conditions may have accounted for some of the cognitive and adaptive skills deficits and future research in this area should try to control for these conditions or recruit patients without these comorbid conditions.

Conclusion

The current study took a neuropsychological approach in order to investigate aspects of functioning in children with ADHD with and without comorbid FASD to help guide improvements to the everyday functioning of these children by suggesting interventions based upon the cognitive and adaptive skills in these two samples. Despite the limitations of this study, some important findings emerged. The statistical analyses indicated that children with ADHD and children with ADHD/FASD have similar cognitive and adaptive skills profiles; however, children with comorbid ADHD/FASD are significantly more impaired in verbal ability, perceptual reasoning, working memory, processing speed, and overall adaptive skills. Given the differences between these two groups in their cognitive and adaptive skills functioning, it is important to understand these groups' respective areas of strengths and weaknesses in order to advance intervention techniques.

The current study took a step forward in helping to make diagnostic decisions based on the similarities and differences between children with ADHD with and without comorbid FASD. Given the data from the current study indicating the significant differences in cognitive and adaptive skills in these two samples, it is imperative that

psychopharmacological interventions be tailored to these two seemingly similar yet different groups, especially as these two groups may respond differently to stimulant medication, the first line of medicinal treatment for ADHD.

Children with ADHD/FASD have many of the same cognitive and adaptive skills deficits seen in children with ADHD without comorbid FASD; however, children with ADHD/FASD are significantly more impaired in these areas. Future research in this area is needed and should address some of the weaknesses identified in this study.

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