**University of Alberta**

# Attention and Executive Functioning of Children with Fetal Alcohol Spectrum Disorders

by

Olivia T. Lestideau ©

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## ABSTRACT

The term Fetal Alcohol Spectrum Disorder (FASD) describes a number of cognitive and behavioural deficits resulting from central nervous system damage caused by prenatal exposure to alcohol. These deficits include many facets of attention and executive functions. Twenty nine children clinically diagnosed with FASD were matched to 29 non-exposed children and administered the three core subtests from the Attention and Executive Functions domain of the NEPSY, which measure planning, set-shifting, organization, sustained attention and shifting attention. Between-group analyses found that the children with FASD performed significantly more poorly than non-exposed children on all subtests. Analyses of rule violations and errors of omission and commission identified diffuse deficits in attention across tasks and difficulty with impulsivity on planning and auditory attention tasks. Results are discussed in relation to practical implications.

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# CHAPTER ONE

## Introduction

### *Background*

Prenatal exposure to alcohol is a pervasive problem affecting children and adults around the world, and is currently one of the most common known causes of mental disability in North America (National Institute on Alcohol Abuse & Alcoholism, 1990). The outcomes associated with prenatal exposure to alcohol are significant and costly, both socially and financially, and are particularly tragic because they are *preventable* (Astley, 2004). A number of alcohol-related disorders fall under the umbrella of *Fetal Alcohol Spectrum Disorder* (FASD; Astley, 2004). There are a number of primary and secondary disabilities that result from prenatal exposure to alcohol. In this context, the term primary disabilities refers to cognitive and behavioural deficits directly related to brain damage, some of which may be recognized at birth. In contrast, secondary disabilities are not present at birth, but are associated with primary disabilities and can, to some extent, be prevented or remediated by interventions. Prenatal exposure to alcohol results in irreversible damage to the central nervous system (CNS), negatively impacting physical, cognitive and behavioural development, and contributing to secondary disabilities such as substance abuse, criminality, and psychopathology (e.g. Barr et al., 2006; Steinhausen, Willms, & Spohr, 1993; Streissguth, Barr, Bookstein, Sampson & Carmichael Olson, 1999). Since the primary and secondary disabilities associated with FASD can have such a profound effect on the day-to-day health and functioning of individuals, efforts aimed at diagnosis, intervention, and prevention are vital for families affected by alcohol abuse.

*FASD: A Brief History*

In 1968 a French physician, Dr. Lemoine, and an American paediatrics resident, Dr. Ulleland, took interest in and began studying groups of children born to alcoholic mothers (Astley, 2007). These children were noticed because they all showed patterns of growth deficit and shared physical abnormalities of the face, heart, and limbs not present in infants whose mothers did not drink during pregnancy (Jones, Smith, Ulleland, & Streissguth, 1973). These children also showed impairments indicative of CNS damage (Jones et al., 1973). In 1973, Jones and Smith published a seminal paper in which they coined the term *Fetal Alcohol Syndrome* (FAS), marking the beginning of intensive efforts to identify and understand individuals exposed to alcohol prenatally. Today, various diagnostic terms, including FAS, partial-FAS (p-FAS), and static encephalopathy describe outcomes of prenatal exposure to alcohol, and fall under the umbrella term FASD (Loock, Conry, Cook, Chudley, & Rosales, 2005).

*Terminology and Diagnosis*

In the decades following the "discovery" of FAS, the diagnostic criteria and terminology became more and more refined. Different approaches to assessment resulted in differences in terminology, making diagnosis a complicated and challenging enterprise. A generally accepted approach to diagnosis is use of the 4-digit diagnostic code, originally put forth by the Washington State FAS Diagnostic and Prevention Network (FAS DPN) in 1997, with the most recent edition published in 2004 (Astley, 2004). In accordance with this code, growth impairment, a characteristic facial phenotype (short palpebral fissues, thin upper lip, and smooth philtrum), evidence of CNS damage, and confirmation of prenatal alcohol exposure are each rated using a 4-

digit scale. There are a total of 256 possible 4-digit codes, each of which falls into one of 22 diagnostic categories (Astley, 2004). These categories are descriptive of disorders falling under the umbrella FASD (FAS or p-FAS), or made up of generic terms relating to the presence or absence of physical markers and CNS damage.

One of the most obvious indicators of prenatal alcohol exposure is signs of dysmorphology, or physical abnormality. Children with FASD are often identified by growth deficits and the presentation of a characteristic facial phenotype. Using the 4-Digit code, growth deficits and facial abnormalities are each ranked according to the magnitude of presentation. A rank of 4 refers to severe presentation, Rank 3 refers to moderate presentation, and Ranks 2 and 1 are mild and no presentation, respectively. When growth deficits are ranked at the 3$^{rd}$ and 4$^{th}$ level, they are referred to as *sentinel physical findings.* Brain functioning is also ranked according to the 4-point Brain Dysfunction Scale using the 4-digit code (Astley, 2004). The four Brain Ranks refer to the clinician's level of certainty that the individual's cognitive and behavioural problems are a result of structural and/or functional brain damage, regardless of whether alcohol exposure is confirmed (since alcohol exposure is ranked separately). Brain Ranks 4 and 3 are classified as *static encephalopathy* (definite and probable brain damage, respectively). Brain Rank 2 is assigned to individuals who present a strong possibility of brain damage, and is also referred to as *neurobehavioural disorder*. Rank 2 is assigned in two circumstances; when the child is too young to be tested comprehensively, or when, upon testing, the evidence for brain damage is too weak to result in a higher ranking, but is too strong to dismiss entirely. Finally, Brain Rank 1 applies to individuals who do not display evidence of brain damage causing cognitive and behavioural problems. All diagnoses are also qualified by the level of certainty that the individual was exposed to alcohol prenatally, with Ranks 3 and 4 describing *alcohol exposed,* Rank 2 describing *alcohol exposure unknown,* and Rank 1 describing *no alcohol exposure.*

Within this paper, the terms FAS and FAE will only be used when describing previous research employing this terminology, otherwise, the term FASD will be used. The sample of participants in this study will also be described as having an FASD, but specifically describes children with either static encephalopathy (alcohol exposed) or neurobehavioural disorder (alcohol exposed).

*Common Outcomes Associated with FASD*

Perhaps the most important diagnostic marker of FASD is damage to the CNS. Individuals who lack the characteristic facial phenotype, but who were nonetheless exposed to alcohol during gestation often show significant cognitive and behavioural difficulties (Randall, 2001). FASDs are increasingly being linked to deficits in executive functioning (Connor, Sampson, Bookstein, Barr & Streissguth, 2000), a term that describes a cluster of higher-level cognitive skills (such as planning, self-regulation and organization) which are thought to be instrumental in normal daily functioning (Welsh, 2002). Children with FASD have been found to show deficits in executive functioning irrespective of whether they had FAS or were non-dysmorphic, alcohol-exposed children (Mattson, Goodman, Caine, Delis and Riley, 1999; Schonfeld, Mattson, Lang, Delis, & Riley, 2001).

CNS damage can also manifest as hard and soft neurological signs, abnormal brain structure, intellectual deficits, and impairments in memory, communication skills, and attention (Loock et al., 2005). Perhaps the most well-known line of research into the cognitive and behavioural outcomes of FASD is the Seattle Prospective Longitudinal study, led by Dr. Streissguth and her colleagues, which included approximately 500 participants and their mothers. Throughout childhood the participants demonstrated cognitive processing delays, poor motor coordination, difficulty with attention and memory, elevated levels of hyperactivity and impulsivity, and poor organization skills (Carmichael Olson et al., 1997; Connor & Streissguth, 1996; Streissguth et al., 1984; 1996; 1999). Over 50% of the participants also struggled with significant secondary disabilities in adulthood, such as disrupted schooling, trouble with the law, confinement, addiction problems, and repeated inappropriate sexual conduct (Streissguth et al., 2004). Also, compared to individuals whose mothers did not engage in binge drinking, individuals exposed to binge-amounts of alcohol on at least one occasion were twice as likely to develop passive-aggressive personality disorder, antisocial personality disorder, or addictions to alcohol and/or drugs (Barr et al., 2006).

It is notable that in the Seattle study the most of the mothers reported drinking amounts of alcohol that were then considered to be social amounts – an average of 2 drinks per day prior to pregnancy recognition, and an average of 5 drinks per week post-pregnancy recognition (Streissguth et al., 1984). The women were predominantly educated, married, and middle-class, and abstained from polydrug use. The evidence accumulated from testing their children indicated that there can be severe neurobehavioural outcomes of moderate alcohol consumption, and there is no such thing as a safe amount of alcohol consumption during pregnancy (Streissguth et al., 1999).

### *The Problem at Hand*

The FASD literature provides invaluable insights into the ways individuals exposed prenatally to alcohol think, learn, and interact. However, the measures of attention and executive functioning that are used in research may not always be consistent with those used in clinical settings with this population, which perpetuates the divide between research and practice. While many tests appearing in the literature are used in clinical settings, very few of them belong to comprehensive batteries, limiting the extent to which they can be compared with measures of other cognitive skills. The *NEPSY: A Developmental Neuropsychological Assessment* (NEPSY: Korkman, Kirk, & Kemp, 1998b) is a popular neuropsychological measure for children, and shows promise with other clinical groups. However, little research has been conducted to validate its use in FASD diagnosis.

### *Purpose of the Present Study*

The purpose of the present study is to provide evidence of clinical utility of the core Attention and Executive Functions subtests of the NEPSY with children with FASD. This will aid clinicians by increasing their confidence that these subtests of the NEPSY accurately distinguish children qualifying for an FASD diagnosis from children who do not have structural and/or functional brain damage. From an epidemiological perspective, accurate and reliable diagnosis is essential before public health workers can determine the extent to which FASD is present in the population (Astley, 2007). To accomplish this end, clinicians need reliable and valid tools to use in the diagnostic process.

*Summary*

The last four decades has seen the discovery of FASD, the development of diagnostic procedures, and rapidly increasing knowledge of the outcomes associated with prenatal alcohol exposure, methods of intervention, and work to prevent it entirely. Studies of attention and executive functioning have risen into the spotlight in recent years, yielding a rich bank of knowledge about specific deficits experienced by individuals with FASD. Before delving into the present study, it is first necessary to describe the work that has set the stage for this study. This chapter served to introduce the basic outcomes associated with prenatal exposure to alcohol, the diagnostic criteria, and the evolution of terminology that has been employed.

Chapter Two will outline the theories guiding the present study, introduce the NEPSY, and describe previous research examining the executive functioning and attention skills of children with FASD. Chapter Three will describe the participants, instrumentation, and the procedure. The results will be reported in Chapter Four, and Chapter Five will contain the discussion portion of the thesis.

# CHAPTER TWO

## Literature Review

### *Introduction*

Individuals exposed to alcohol during gestation often present with a number of cognitive and behavioural deficits, regardless of whether they meet the full diagnostic criteria for FAS. Among the cognitive deficits in this population are impairments in attention and executive functioning. In his theory of dynamic functional systems, Luria postulated that executive functioning and attention are dependent upon the integrity of the frontal lobes and their connections with practically every other part of the brain. Definitions of executive functions usually described them as being future- or goal-oriented behavioural processes (e.g. Denckla, 1996; Eslinger, 1996; Welsh, 2002). These processes include planning, set-shifting, organization, inhibition, and working memory, although there is disagreement whether inhibition and working memory are executive functions, or cognitive processes that underlie and enable normal executive functioning (Eslinger, 1996; Kodituwakku, 2007; Welsh, 2002).

The research at hand will be framed within Luria's theory of the cerebral basis of mental activity, described more fully in the next section. Since the NEPSY is grounded in Luria's theory, it is important to include a discussion of his work in the present study. Luria's ideas about the interconnections between the three functional units also mirror more recent research looking at the frontal-subcortical circuits and their relationship to executive dysfunction (Masterman & Cummings, 1997).

After outlining Luria's theory, the NEPSY, a neuropsychological test for children will be introduced. The NEPSY is grounded in Luria's theory but also incorporates modern child neuropsychological assessment techniques. It provides measures of executive functioning and attention, and shows promise as a tool for identifying children with brain damage resulting from prenatal alcohol exposure. After introducing the NEPSY, a selection of the executive functioning and attention literature will be reviewed, providing the background for the hypotheses of the current study.

*Theoretical Background: A. R. Luria: Dynamic Functional Systems*

Luria was a groundbreaking Russian neuropsychologist, who relied on his extensive knowledge of the human brain to develop a neurologically grounded theory of cognitive processing. Within Luria's theory is an explanation and description of how the brain is organized into three interdependent functional units, which further subdivide into primary, secondary and tertiary zones (Luria, 1973). The first functional unit commands the *regulation of tone, waking, and mental states*, which sets the stage for all forms of conscious activity. Within this unit, connections between the brainstem and subcortex and the frontal cortex and thalamus control arousal and simple attention. These interconnections facilitate self-monitoring and inhibition. That is, the areas of the brain implicated in this unit (e.g. the brain stem) not only control levels of arousal and wakefulness, but are in turn influenced by the second and third functional units. The second unit – the *reception, analysis and storage of information* – is responsible for encoding sensory perception and processing sensory information in abstract ways. This unit is composed of the medial areas of the temporal, parietal, and occipital lobes and information processing in these regions of the brain is largely mode-specific because clusters of neurons in these areas become highly differentiated during fetal development. Finally, the third functional unit involves the *programming, regulation, and verification* *of activity*, and orchestrates executive functions and attention. The activity of this functional unit takes cognition beyond sensation and perception, and regulates higher-order processes such as setting goals, planning, and using feedback to modify plans. The brain structures anterior to the precentral gyrus comprise this unit, including the motor cortex and the frontal lobes. Luria wrote of the extensive connections between the frontal lobes and subcortical parts of the brain, as well as the drastic changes in daily living skills and personality that can result from damage to these regions. The frontal lobes provide an important regulatory influence over the activity of the posterior cortical regions and subcortical structures, enabling processes like voluntary attention, planning and goal setting, and complex (working) memory.

Luria proposed that cognitive functions are a product of interdependent, dynamic, and functional systems (Luria, 1973). He proposed this theory of functional systems partly because certain functions (planning, for example) cannot be ascribed to single structures in the brain, and require coordination and communication between a number of structures. He also noted there are many functional connections between different parts of the brain, and cognition results from different cortical zones working in concert. Thus any outcome or response can be achieved through multiple neural mechanisms. A second key proposition in Luria's theory was that the localization of higher mental processes in the cortex is dynamic and shifts as a result of both development and training (Luria, 1973). Citing Vygotsky, Luria agreed that damage to lower cortical areas in childhood can lead to lifelong impairment in higher-order thinking, whereas damage to the same areas in adulthood may impair lower-level activities, but leave higher-order cognitive processes intact, a position also referred to as "dynamic localization" (Luria, 1973).

Luria's theory of functional systems and his observations of the influence of development on these systems influenced more recent work looking at executive functioning. Subsequent research has shown that executive functions have specific developmental trajectories, and involve cooperation between numerous areas of the brain (Garon, Bryson, & Smith, 2008; Stuss & Benson, 1984; Welsh, 2002).

## *Attention and Executive Functions*

### *Background*

The term executive functioning describes a set of complex mental processes that have proven difficult for researchers and theorists to define operationally. Welsh (2002) provides an important overview of executive functioning, describing it as a cluster of complex cognitive skills – including planning, inhibition, set-shifting, organization, and fluency – that are enabled by the coordination of basic cognitive processes that help the individual pursue future, goal-oriented pursuits. Eslinger (1996) also clarifies how executive functioning is distinct from attention and memory by emphasizing executive functioning is future-orientated and is what allows us to pursue goals in the face of adversity and delayed gratification.

Some researchers suggest executive functions can be explained by a balance, or interaction between working memory and inhibition (Denckla, 1996; Welsh, 2002). Inhibition is the ability to engage in appropriate behaviour despite the impulse to respond in a well-learned or reflexive manner (Welsh, 2002). Deficits in inhibition have a range of descriptions, many suggestive of *outcomes* of poor inhibition, including "poor judgement," "lack of foresight," and "inability to delay gratification" (Welsh, 2002, p. 157). Definitions of working memory include the ability to encode information into short-term memory *and* the ability to manipulate that information for the purpose of producing a novel response in the pursuit of a goal (Welsh, 2002). Following a limited capacity model of cognitive functioning, it is hypothesized that when a person's working memory is taxed, his or her ability to inhibit prepotent responses diminishes; likewise, taxing inhibition will reduce working memory capacity (Welsh, 2002). Individuals with FASD usually have deficits in both working memory and inhibition, and also seem to be impaired on tasks measuring executive functions such as planning and set-shifting (e.g. Connor et al., 2000; Kodituwakku, Handmaker, Cutler, Weathersby, & Handmaker, 1995).

Luria's theory of dynamic functional systems is especially pertinent to the study of executive functioning (Welsh, 2002). Mentioned previously, activities of the third functional unit can be described as executive functions. This unit relies on frontal lobe integrity and is involved in voluntary attention, working memory, the formation of intention, planning, self-regulation, and monitoring behaviour to conform to plans and feedback from the environment (Luria, 1973). In his description of the interaction between the first and third functional units, Luria distinguished between involuntary (reflexive) and voluntary (purposeful) attention. The former was observed to be controlled by the ascending reticular activating formation and superior brain stem, while the latter depended on the limbic cortex and frontal lobes.

*The Neurological Basis of Executive Functioning*

Research into executive functioning has its roots in studies of adults with frontal lobe damage (Luria, 1973; Welsh, 2002). Early studies examined patients with focal damage to the frontal lobes, most commonly caused by gunshot wounds, tumours, and frontal leucotomies meant to treat psychopathology. These studies described a set of common behaviours resulting from frontal lobe damage, which would later be called *dysexecutive syndrome* (Baddeley, 1996). Individuals with dysexecutive syndrome are paradoxically described as either passive and inert, or uninhibited and volatile (Baddeley, Della Sala, Papagno, & Spinnler, 1997). They often show an astounding lack of behavioural insight as well as impulsivity, egocentricity, and dramatic changes in motivation and affect (Masterman & Cummings, 1997; Stuss & Benson, 1984). Individuals with dysexecutive syndrome are known to be prone to confabulation (Papagno & Baddeley, 1997) and to have difficulty performing sequential responses, maintaining and shifting response sets, monitoring their own behaviour, and resisting distraction (Masterman & Cummings, 1997; Stuss & Benson, 1984).

Luria (1973) reported the frontal lobes are essential to the regulation of behaviour and higher cognitive processes, and noted lesions to different areas of the frontal lobes often result in different patterns of deficit. We now know that frontal-subcortical connections fall into 5 discrete parallel circuits (Masterman & Cummings, 1997). Two of these circuits are particularly instrumental in executive functioning: the dorsolateral and orbitofrontal circuits. In the former, information passes from the dorsolateral prefrontal cortex to the caudate nucleus, the globus pallidus and substantia nigra, the thalamus, and back to the dorsolateral prefrontal cortex. The dorsolateral circuit is instrumental in executive functions such as planning, set-shifting, and organization. In the orbitofrontal circuit, information is relayed from the orbitofrontal cortex to the caudate nucleus, the globus pallidus and substantia nigra, then to the thalamus and back to the orbitofrontal cortex. This circuit is involved in emotional regulation and social functioning, and damage can result in social and emotional disinhibition and lability, impulsivity, and a lack of foresight and judgement (Masterman & Cummings, 1997).

*The Neurological Basis of Deficits in Attention*

It has been known for many decades that lesions in the frontal lobes and the limbic system impede attentional processes (Luria, 1973). Deficits in attention, especially impulsivity and impaired set-shifting, are linked to frontal lobe dysfunction as well as lesions to areas of the temporal and parietal lobes and the brain stem (Luria, 1973; Mirsky et al., 1991; Spadoni et al., 2007). Lesions in structures in the limbic system and basal ganglia result in deficits in focused and sustained attention, execution, and encoding, while damage to the frontal lobes is more closely associated with impaired shifting attention (Mirsky et al., 1991). The frontal lobes are also active in sustained attention and resistance to distraction, and patients with damaged frontal lobes commonly have deficits in "concentration and effort to specific demands" (Stuss & Benson, 1984, p. 99). Luria (1973) also explains that frontal lobe damage can result in the inability to ignore irrelevant stimuli, since the frontal lobes are instrumental in inhibiting responses and maintaining goal-directed behaviour.

*FASD and Deficits in Executive Functioning and Attention*

Both animal and human models show that the teratogenic effects of alcohol on the fetus are expressed as physical damage to the brain, particularly to structures connected in the frontal lobes, and are implicated in executive functioning and attention (Mattson et al., 1996; Mihalick, Crandall, Langlois, Krienke, & Dube, 2001; Sowell et al., 2002; Wass, Persutte, & Hobbins, 2001). Prenatal exposure to alcohol appears to affect the functioning of the dorsolateral prefrontal and orbitofrontal circuits, as it is associated with a decrease in size of the basal ganglia (most prominently the caudate) beyond general reductions in brain size (Mattson et al., 1996), as well as abnormalities in areas of the frontal and parietal lobes (Spadoni, McGee, Fryer, & Riley, 2007). Interestingly, damage to the basal ganglia, particularly the caudate, is also thought to be implicated in deficits in response inhibition (Mattson et al., 1999). In addition to damaging the basal ganglia, prenatal exposure to alcohol has a teratogenic effect on other areas of the brain including the cerebellum, corpus callosum, hippocampus, and thalamus (Autti-Rämö et al., 2002; Lebel et al., in press; O'Hare et al., 2005; Mattson, Schonfeld, & Riley, 2001; Schonfeld et al., 2001; Spadoni et al., 2007). Because the functioning of these areas and (by implication) the frontal lobes is interrupted in individuals with FASD, it is understandable why they also show deficits in executive functioning and attention.

In a review of the literature, Kodituwakku (2007) recently suggested that although a cognitive-behavioural phenotype of FASD has never been agreed upon, it may be described as the "*generalized deficit in processing complex information*" and he hypothesized that the ability to integrate information may be a central deficit in this phenotype (Kodituwakku, 2007, p. 199). This hypothesis has some support from a study that found alcohol-induced lesions to the medial prefrontal cortex in rats interfered with their ability to transfer problem-solving to new situations despite relatively normal initial learning (Mihalick et al., 2001). The authors of this study suggested response inhibition – a common deficit associated with prenatal alcohol exposure – is required for the transfer of learning in set-shifting situations (e.g. reversal problems), and individuals exposed to alcohol prenatally may have difficulty overcoming prepotent response biases (i.e. response inhibition) acquired in initial learning situations (Mihalick et al., 2001). As outlined previously, the ability to inhibit one's responses has been theorized to underlie executive functions (Welsh, 2002), and is predominantly a function of Luria's third functional unit. Although few researchers examining executive dysfunction in individuals with FASD directly discuss the potential influence of response inhibition, it has been implicated in a number of studies reporting specific deficits in executive functioning in this population, including planning, set-shifting, and organized search skills.

Planning is particularly important in effective daily living and involves using foresight and strategy, in addition to the inhibition of reflexive responses. A common test of planning is the tower task, which takes various forms in standardized tests, including the Tower of Hanoi, the Tower of London, the Tower of California, the Progressive Planning Test and the Tower subtest of the NEPSY, which all have slightly different administration rules and instructions to participants. A number of researchers have found children with FASD complete fewer items correctly, commit more errors of commission, and violate the rules more frequently than non-exposed children (Kodituwakku et al., 1995; Korkman, Kettunen, & Autti-Rämö, 2003; Mattson et al., 1999). Both rule violations and errors of commission are indicative of poor inhibition and information processing (Kodituwakku, May, Clericuzio, & Weers, 2001; Mattson et al., 1999). Furthermore, children's performance appears to deteriorate as the tasks become more complex and more stressful (Kodituwakku et al., 1995; Korkman et al., 2003). It is likely that increasingly complex items tax the functioning of the third functional unit (Luria, 1973) and add to working memory demands (Kodituwakku et al., 1995), resulting in fewer resources available for inhibiting reflexive responses (Welsh, 2002).

Like planning, set-shifting is also relevant to daily living and problem-solving. Set-shifting is the ability to change one's pattern of response, and to adapt to changing circumstances for effective problem-solving. Mattson and her colleagues (1999) found that set-shifting ability (assessed using the Stroop Test and Trail Making Test from the Delis-Kaplan Executive Functioning Scale: D-KEFS; Delis, Kaplan, Kramer, & Ober, 1997) was impaired in children with FAS but not in alcohol-exposed children lacking the facial features of FAS or children in the control group. Because the children with FAS had enormous difficulty with tasks requiring adequate mental preservation of task rules and self-monitoring of alternations between stimuli (i.e. the switching tasks) this study adds to other evidence (e.g. Kodituwakku et al., 1995) that intact working memory skills are required for normal executive functioning. Children with FASD, regardless of their specific diagnosis, also consistently have difficulty with the WCST (Connor et al., 2000; Kodituwakku et al., 1995; Kodituwakku et al., 2001). Like their performance on planning tasks, children with FASD commit more errors of commission, and also appear to have difficulty using feedback to guide changes in behaviour when completing set-shifting tasks (Kodituwakku et al., 1995; Kodituwakku et al., 2001).

Another executive function that has been assessed in children with FAS is organized search skills, although research examining this skill is limited. Organized search skills seem to be relatively unimpaired in children with prenatal exposure to alcohol, as children with FAS performed similarly to unexposed children on the Trail Making task on the D-KEFS (Mattson et al., 1999) and the Visual Attention subtest of the NEPSY (Korkman et al., 2003).

Individuals with FASD appear to be differentially impaired on tasks measuring different facets of attention, and show greater impairment in complex forms of attention (e.g. Coles et al., 1997). Focused attention, which can be thought of as a simple form of attention appears to be largely unimpaired in both children and adults with FASD (Coles et al., 1997; Coles, Platzman, Lynch, & Freides, 2002; Conner et al., 1999; Kerns, Don, Mateer, & Streissguth, 1997). However, there is disagreement whether individuals with FASD find sustained attention difficult. Nanson and Hiscock (1990) found evidence that children with FAS show impairment on tests of sustained attention, while Coles and her colleagues (1997, 2002) did not. Studies of adults have also found evidence for deficits in sustained attention, using the Attention Process Test and the Consonant Trigrams Test (Connor, Streissguth, Sampson, Bookstein, & Barr, 1999; Kerns et al., 1997). In addition to possible deficits in sustained attention, complex forms of attention – shifting and encoding – are affected (Coles et al., 1997; Connor et al., 1999; Kerns et al., 1997). Error score analyses indicate individuals with FASD can be characterized as being more inattentive than impulsive (Coles et al., 2002; Connor et al., 1999).

*Challenges in Measuring Executive Functioning*

Consistent with Rasmussen's (2005) review of literature examining executive functioning and working memory deficits in individuals with FASD, the studies cited above share some limitations. Although some did not use control groups, those that did matched their participants for age, gender and ethnicity fairly consistently. Most of the studies discussed previously limited their samples to children whose IQ scores were 70 or above. Using samples of children with IQ scores above 69 limits the ability to generalize findings to lower-functioning children with FAS. Finally, an agreed-upon definition of exactly what constitutes executive functioning is missing, and few researchers link their findings to established theoretical frameworks. The multiplicity of measures used in assessing facets of executive functioning poses potential problems in making comparisons across studies, in part because of the measurement error introduced by differences in administration rules and instructions to participants. Consumers of this literature must be wary of using research showcasing a particular measure to support their use of a similar but different measure.

## *NEPSY: A Developmental Neuropsychological Assessment*

### *Background*

The NEPSY (Korkman et al., 1998b) is a comprehensive neuropsychological battery, meant for use with children between the ages of three and 12. Grounded in Luria's theory of dynamic functional systems, the NEPSY employs assessment techniques from child neuropsychology. Its hallmark is providing a flexible, development-oriented approach to the assessment of neuropsychological functioning in children (Ahmad & Warriner, 2001). The first version of the test, published in 1980, was in Finnish and it was translated into English in 1998. The English version was standardized and normed on a population of North American children, stratified to reflect the 1995 U. S. census population (Korkman et al., 1998b).

The NEPSY is one of a handful of complete batteries that can be used with both younger and older children, and has potential for use in clinical settings across Canada for the purpose of determining brain functioning in children who have been exposed to alcohol prenatally. Despite its potential there have been few attempts to validate it with this special population. Since the NEPSY has potential as an alternative to other batteries, researchers have been encouraged by the test authors to continue to conduct studies that demonstrate its clinical validity with a range of special populations.

Korkman et al. (1998b) outline four primary uses of the NEPSY: 1) to identify subtle neuropsychological deficits that may interfere with learning; 2) to identify and describe brain dysfunction, and how deficits in one functional domain may affect other domains; 3) to track long-term outcomes and development; 4) to assess typical and atypical functioning and development in children.

*Structure and administration*

The NEPSY is organized into five core domains with a total of 27 subtests. The domains assessed by the NEPSY are: 1) Attention/executive functions, 2) Language, 3) Sensorimotor functions, 4) Visuospatial processing, and 5) Memory and Learning. Each domain consists of two or three core subtests and up to three expanded subtests, depending on the age of the child. Administration of the entire test is supposed to be flexible, allowing the clinician to take into consideration the child's age, the reason for referral, and to follow-up on any bizarre scores in core subtests. In accordance with Luria's theory of dynamic functional systems, skills demonstrated in the core domains are presumed to interact and work together for overall neuropsychological functioning, and focal brain damage should produce patterns of poor performance across the NEPSY domains. For example, given Luria's (1973) observations of poor attention, memory, and self-regulation among patients with frontal lobe damage, one would expect children with neurological insult to this area and/or other cortical and subcortical structures functionally connected to the frontal lobes will show deficits on tasks within the Attention and Executive Functions domain.

*Clinical Utility*

Clinical utility, or external validity, of a test is usually supported through evidence that it has the ability to discern between different groups of individuals. There has been increasing research supporting the use of the NEPSY with atypical populations, including children with spina bifida (Riddle, Morton, Sampson, Vachla, & Adams, 2005), high-functioning autism (Hooper, Poon, Marcus, & Fine, 2006), and emotional and behavioural disorders (Mattison, Hooper, & Carlson, 2006). However, given the NEPSY shows promise and is likely used in FASD clinics across Canada, there has been limited research into its clinical validity with this population. Studies with special populations have thus far shown that children with certain neurological conditions display distinct profiles on the NEPSY. The validity studies cited in the test manual indicate that a number of groups of children with clinical concerns nearly always score significantly below typically-developing children at both the domain and subtest level (Korkman et al., 1998b). Independent analyses also support these preliminary findings. Schmitt and Wodrich (2004) compared three groups of children: one group had a variety of neurological concerns, another group had scholastic concerns, and the third was a control group. As expected, the neurological concerns group was distinguished by greater difficulty with Attention and Executive Functions tasks, while the learning disability group had greater difficulty with Memory and Learning. Both groups had difficulty with Language and Sensorimotor subtests. However, when IQ was controlled, only two domains (Language and Sensorimotor functions) continued to emerge as significant deficits for both groups. Another study was conducted by Hooper and his colleagues (2006) in which the authors focused on children with high functioning autism (HFA), and reanalyzed data cited in the manual, controlling for IQ effects. They found that even after controlling for IQ, the HFA group had lower scores on over half of the core subtests. They concluded that the NEPSY provides unique information not assessed by ability tests, and is capable of distinguishing children with HFA from typically-developing children (Hooper et al., 2006). The NEPSY also shows promise in the diagnosis of serious emotional and behavioural disorders in children (Mattison et al., 2006). Children with emotional and behavioural disorders, who also qualify for special education services, or who have neurological risk factors can be identified by low scores on the Attention/Executive Functioning and Language domains of the NEPSY. Interestingly, more than 25% of the total sample had been exposed to alcohol and/or drugs prenatally, which may explain low scores on executive functioning and attention tasks (Mattison et al., 2006).

To date there is very limited research employing the NEPSY to study executive functioning and attention in children with FASD. Korkman and her colleagues (Korkman, Autti-Rämö, Koivulehto, & Granström, 1998a; Korkman et al., 2003) divided a sample of children into groups according to the duration of exposure to alcohol during gestation, and reported findings from two data collection points using a prospective sample of children from age five through to early adolescence. They found that in early childhood (using the 1988 Finnish version of the NEPSY) participants had IQ scores in the normal range, but were impaired on tests of attention, receptive language, naming, and visual-motor production (Korkman et al., 1998a). Duration of alcohol exposure also played a significant role in the presence or absence of deficits; children exposed only in the first trimester showed minor, non-significant differences from the control group, with only attention scores approaching two standard deviations below the mean of the standardization sample (Korkman et al., 1998a). Children whose mothers had stopped drinking after the second trimester scored much lower than the control group, and deficits appeared to be quite diffuse (Korkman et al., 1998a). In early adolescence, the same participants continued to show global, diffuse deficits in neurocognitive functioning, and the role of duration of exposure remained significant for six of the 15 NEPSY subtests (Korkman et al., 2003). While participants showed deficits in all of the NEPSY domains, they appeared to have the most difficulty with complex tasks that taxed attention and working memory skills (Korkman et al., 2003).

Another study examining neurodevelopmental abnormalities in 60 children with FASD found that domain scores on the Attention and Executive Functions, Language, and Memory and Learning domains were below average, especially among older children (Hanlon-Dearman & Penner, 2007). While this group showed strengths and weaknesses across domains of the NEPSY, a subtest score analysis revealed significant deficits in some subtests within domains that seemed to represent only mild deficits. These preliminary studies of the clinical utility of the NEPSY with children with FASD remain inconclusive regarding whether the Attention and Executive Functions subtests are good measures of these skills in children exposed to alcohol prenatally, and whether this portion of the NEPSY should be used to determine the neuropsychological functioning of these children.

The studies supporting the clinical validity of the NEPSY share some limitations. Many were disadvantaged by the absence of a control group, introducing potential confounds associated with geographic location, culture and socioeconomic status, to name a few variables. Similarly, group differences may not always have been detected since a number of the studies had modest sample sizes. However, despite these limitations, the studies discussed above demonstrate that children from a number of clinical populations can be distinguished from typically developing children using the NEPSY. This battery shows promise and value as a clinical tool, particularly with children who suffer from brain damage due to prenatal alcohol exposure.

### *Summary*

Children with FASD are often described as impulsive, immature, easily distracted, eager to please, and showing difficulty remembering and applying rules, achieving goals, and interacting with others appropriately. These behaviours can lead to secondary disabilities later in life such as academic and occupational failure and trouble with the law. Executive functions are purported to play a central role in the development of behavioural competency and normal daily living skills. For example, the inability to plan and execute a sequence of actions, and impairment in the ability to adapt to changing circumstance by employing set-shifting would make it very difficult to prepare for a job interview, complete grocery shopping independently, or complete homework efficiently and on time. Coupled with deficits in attention and feelings of frustration resulting from consistently facing obstacles and failure can compound an individual's problems, especially when an adequate support system is lacking.

Research with children has shown that prenatal exposure to alcohol damages specific structures in the brain, which are linked with deficits in attention and executive functioning. These deficits may be exacerbated by underlying weaknesses in working memory and inhibition. Children with FASD also have difficulty with facets of voluntary attention, beginning in early childhood and persisting through adulthood. Generally, as tasks become more complex, the performance of these individuals in testing situations breaks down.

The NEPSY, a popular neuropsychological battery, can be used in the assessment and diagnosis of brain dysfunction in children with FASD, but to date has not been extensively examined with this population. Given the documented deficits in attention and executive functioning summarized in this chapter, children with FASD should show significant weaknesses on the Attention and Executive Functions domain of the NEPSY in comparison to typically developing children. Indeed, research participants exposed to alcohol prenatally seem to consistently perform worse than control participants on subtests in this domain (Korkman et al., 2003).

## *The Present Study*

One of the strengths of the NEPSY is that it can be administered in a flexible way to suit the examiner's research or clinical needs. Consistent with this approach, the Attention and Executive Functions domain was administered to children participating in the present study. The decision to include only the three core Attention and Executive Functions subtests was made in consideration of the availability of archival data belonging to local children with FASD, which did not include the entire NEPSY battery, and time and resources did not permit the recruitment of such a large sample of children with FASD.

### *Hypotheses*

Given previous research highlighting children with FASD struggle with planning, set-shifting, attention, and inhibition, it is expected the children with FASD in this study will perform more poorly on the Tower, Auditory Attention and Response Set, and Visual Attention subtests compared to the control group. Thus it follows the children with FASD are also expected to obtain lower domain scores relative to the control group. Since the goal of this study is to validate the use of a portion of the NEPSY with children with FASD, significant between-group differences at the subtest level will be taken to suggest the Attention and Executive Functions domain is a useful and valid tool for the diagnosis of FASD. According to Luria's (1973) theory, complex processes like planning, set-shifting, and organization are activities of the third functional unit (i.e. the frontal lobes), which programs, regulates and verifies all cognitive activity. The frontal lobes also interact with structures involved in the first and second functional units. Inattention can be thought of as the result of disrupted functioning of the frontal lobes, the basal ganglia, and the brain stem, while impulsivity may be more appropriately described as problem with the frontal lobes and motor cortex (Luria, 1973). The results of the error score pattern analyses are expected to highlight that children with FASD have difficulty with attention and impulsivity on all three subtests evidenced by higher rates of rule violations, errors of omission, and errors of commission relative to children in the control group.

*Significance of the Present Study*

Damage to the brain is arguably one of the most injurious outcomes of prenatal exposure to alcohol (Astley, 2004). Given previous research showing similarities in cognitive functioning among individuals with and without the facial features and growth deficiency associated with FASD (e.g. Mattson & Riley, 1999; Schonfeld et al., 2001), it is prudent for researchers to continue to examine the neuropsychological functioning of individuals exposed to alcohol prenatally. In addition, since clinicians have so many choices between neuropsychological tests, it is important to ensure the ones used in the diagnosis of FASD are valid with this population.

Errors scores are frequently used for clinical interpretation of examinees' approach-to-task, and provide clinically useful supplemental information, however, a limited number of studies reviewed in this chapter reported analyses of error score patterns. Of the studies employing tower tasks reviewed previously, only Mattson and her colleagues (1999) reported results for rule violations. They found children exposed to alcohol prenatally committed significantly more rule violations than unexposed children. There is a similar dearth of research reporting patterns of errors of omission and commission; one study assessing adults with FASD reported they committed more errors of omission and commission on auditory and visual attention tasks (Connor et al., 1999). In addition, Nanson and Hiscock's (1990) study found children with FASD made significantly more errors of commission on two visual attention tasks compared to non-exposed children. The present analyses will hopefully shed light on the reasons children with FASD perform poorly on the Attention and Executive Functions subtests on the NEPSY by describing how they approach and execute tasks. Gaining an understanding of how children with FASD process information and approach problem-solving will assist professionals working with children in this population develop interventions and remediation programs. With effective intervention individuals with FASD may cope better with their primary cognitive disabilities and experience fewer secondary disabilities.

By providing evidence that specific subtests of the NEPSY can be used to distinguish children who have an FASD from children who do not, this study may increase clinicians' confidence in the clinical validity of the Attention and Executive Functions domain of the NEPSY. The research at hand also addresses some of the limitations in previous executive functioning research by including a bigger sample size with a matched control group. This study also, through its focus on children with previously quantified brain damage (i.e. Brain Ranks 2 and 3), provides a more detailed description of how they approach problem solving.

# CHAPTER THREE

## Research Design and Methodology

### *Overview*

Using three sources of data, differences in aspects of attention and executive functioning among children with and without FASD were examined. Using a cross sectional design employing both archival and current data, the performance of children diagnosed with FASD was compared to the performance of a group of typically developing children on the three core subtests from the Attention and Executive Functions domain of the NEPSY (Korkman et al., 1998b). The sample, measures, procedure and statistical analyses will be described in this chapter.

### *Sample*

Archival NEPSY protocols were obtained for a group of 29 children formally diagnosed with an FASD. Protocols belonging to 15 of the participants in this group were obtained from FASD Clinical Services at the Glenrose Rehabilitation Hospital in Edmonton, Alberta. A team of professionals at this clinic follows the FAS Diagnostic and Prevention Network four-digit code and the Canadian Medical Association's guidelines. The other 18 children had gone through the same diagnostic process, but their NEPSY data had been gathered for a different research study, for which this author assisted with data collection. Twenty one children in the FASD group had been diagnosed with either neurobehavioural disorder, alcohol exposed, or static encephalopathy, alcohol exposed (i.e. Brain Ranks 2 or 3; Astley, 2004) and while the remaining eight children had also been diagnosed at the Glenrose Rehabilitation Hospital, information about their Brain Ranks was not available. The mean age for children in the FASD group was 8 years and 7 months (*SD* = 17.7 months), and ages ranged from six to 11 years. There were 18 boys and 11 girls. Other demographic information – including parental education, family structure, and ethnicity – was unavailable for the children with FASD.

Thirty six children were recruited for the control group through extracurricular recreation programs in Edmonton as well as an elementary school in a local suburb. Data collection began in August 2007 and concluded in February 2008. A health history questionnaire was completed by the parents/guardians of each potential participant, which was designed to ensure the exclusion of children with a number of neurological risk factors potentially affecting typical brain development. The exclusionary criteria were history of: epilepsy/seizures, encephalitis, meningitis, brain surgery, stroke, concussion/mild traumatic brain injury, loss of consciousness, ADHD, Tourette's Syndrome, Autism/Asperger Syndrome, and FASD. A total of seven children were excluded, leaving 29 children in the control group. Of the children excluded, two met one or more of the exclusionary criteria, two were absent and could not be tested, one did not speak English, one decided to leave partway through testing, and one child's parents sent in two consent forms indicating disagreement as to whether he could participate.

There were 16 boys and 13 girls in the control group. They had a mean age of 8 years and 11 months (*SD* = 15.1 months), and ages ranged from six to 11 years. Children in the control group were matched to children in the FASD group on the variables of age and gender whenever possible, but 8 pairs of participants were mismatched in some way. One pair of children were mismatched for gender only and four pairs of children were mismatched for age only (age differences ranged from nine to 13 months). Three additional pairs of children were mismatched for both age and gender (age differences ranged from five to 12 months). A one-way ANOVA revealed the two groups were not significantly different in age, $F(1, 57) = 0.905$, *ns*, and a chi-square test revealed similar proportions of boys and girls in each group, $\chi^2(1, N = 58) = 0.55$, *ns*.

*Instrumentation*

The three core subtests from the Attention and Executive Functions domain of the NEPSY were presented to all participants (Korkman et al., 1998b). The Attention and Executive Functions domain measures inhibition, planning, set-shifting, focused, sustained and shifting attention, and figural fluency (Korkman et al., 1998b). This domain of the NEPSY was chosen for study because it assesses multiple facets of attention and executive functioning using a consistent and carefully selected normative sample. It is also consistently used by psychologists at the Glenrose Rehabilitation Hospital in the assessment and diagnosis of children exposed to alcohol prenatally, providing access to a convenience sample for this study. Because children in the FASD group were rarely administered the supplemental subtests from the Attention and Executive Functions domain, these subtests were excluded from the present study. Korkman and her colleagues report adequate psychometric properties for the Attention and Executive Functions domain, with reliability coefficients for the three core subtests ranging from $\alpha = .71 - .82$. The three core subtests required to calculate the domain standard score are the Tower, Auditory Attention and Response Set, and Visual Attention subtests.

The *Tower* subtest is an adaptation of Shallice's Tower task (Korkman, 1999) in which the child is asked to replicate patterns presented in picture format using three coloured balls on three pegs. For each pattern the child is told how many moves he or she can make, making it necessary for him or her to plan a sequence of moves before beginning. This task is a measure of planning and non-verbal problem-solving. In addition to a subtest scaled score, qualitative observations of rule violations (e.g. moving two balls at once) are tallied, compared to base rates, and interpreted as signs of impulsivity. Using these base rates, a child's raw number of rule violations is classified as *well below*, *below*, *borderline*, *expected*, or *above expected* in comparison to his or her same-age peers.

The *Auditory Attention and Response Set* subtest is presented in two parts, yielding a scaled score for the entire subtest and scaled scores for Part A and Part B. In Part A (the Attention task) the child is presented with coloured tokens and a long sequence of words is presented orally from an audio tape. The child is instructed to place a red token in the box whenever he or she hears the word *red*. Part A is a measure of focused attention, sustained auditory attention, and inhibition, and the stimulus is designed to be quite uninteresting, so children with attentional difficulties should be particularly prone to lapses in attention. Part B (the Response Set task) is presented to the child in the same way, but he or she is instructed to place a yellow token in the box whenever the word *red* is presented, a red token whenever the word *yellow* is presented, and a blue token in the box whenever the word *blue* is presented. Thus Part B is more complex and measures shifting auditory attention, inhibition and set-shifting. In both Part A and Part B the frequency of errors of omission and commission can be compared to base rates from the normative sample to determine if levels of inattention and impulsivity are within developmentally-typical limits. The same classification terms used for rule violations apply to errors of omission and commission.

The *Visual Attention* subtest is a timed task and is also presented in two parts varying in complexity. There are different stimuli for preschool and school-aged children, and only the stimuli presented to children ages five to 12 will be described. In Part A the child is presented with a booklet with a random array of drawings and he or she is instructed to mark all the drawings that match the target drawing of a cat at the top of the page. In Part B the child is presented with a structured array of drawings of faces in the same booklet. There are two target faces at the top of the page and the child is instructed to mark every face that is identical to either of the ones at the top of the page. This subtest measures organized visual search skills and focused and sustained visual attention. Speed and accuracy are recorded as qualitative observations, and errors of omission and commission are measures of inattention and impulsivity. The same classification terms used in the Tower and Auditory Attention and Response Set subtests are employed for errors on the Visual Attention subtest.

## *Procedure*

With the approval of the University's Health Research Ethics Board, data was obtained from the Glenrose Rehabilitation Hospital FASD Clinical Services in the summer of 2007, when the recruitment of participants for the control group began. Participants for the control group were recruited via YMCA Edmonton recreation program directors and one elementary school principal. The parents of potential participants were sent information packages containing an information letter, a consent form, and the health history questionnaire. Children whose parents had completed and returned the forms to the program/school were then tested at their respective recreation program or school by the principal investigator. Before testing began, the subtests were introduced and explained to each child and assent was sought.

Data belonging to children with FASD had been rendered anonymous prior to being included in this research by removing names, birthdates and dates of testing and giving each child an ID number, so no further privacy measures were taken. Consent and assent forms belonging to children in the control group were separated from the NEPSY protocols and health history questionnaires to protect participants' privacy. In addition to determining eligibility for participation, the health history questionnaire was used for reporting the demographic characteristics of the participants in the control group. Domain and subtest scores as well as rule violations and errors of omission and commission on the NEPSY were transcribed into SPSS version 16.0 (SPSS Inc., 2007) for statistical analyses.

*Statistical Analyses*

Between-group comparisons of the domain and subtest scores were conducted with univariate analyses of variance (ANOVA). The first set of ANOVAs compared the mean raw sums of standard scores (for the domain) and scale scores (for each subtest) of each group. Although the two groups had been matched for age, the ANOVAs were repeated with age entered as a covariate. Between- and within-group comparisons of performance on each half of the Auditory Attention and Response Set subtest were conducted using a repeated measures ANOVA.

Because of the large age range of participants in this study, error score pattern analyses were conducted two ways, using raw frequencies of errors as well as developmental classifications (determined from base rates in the NEPSY manual). First, univariate ANOVAs using raw frequencies were calculated for each type of error on each subtest, with age included as a covariate. Then, the developmental classifications of each type of error were grouped into two developmental levels, where *well below, below* and *borderline* classifications were grouped into a single *developmentally inappropriate* level and the *expected* and *above expected* classifications were grouped into a single *developmentally appropriate* level. Using these new variables, chi-square tests were calculated, with the proportion of children in the control group falling into the two classifications entered as the expected values to which the distribution of children in the control group was compared.

# CHAPTER FOUR

## Results

### *Domain and Subtest Group Differences*

The performance of children in the FASD and control groups on the Attention and Executive Functions domain and its three core subtests were compared using ANOVA. The children with FASD performed significantly more poorly than the children in the control group on all measures; results are reported in Table 4.1, with means and standard deviations describing standard and scale scores, and $F$ and $\eta_p^2$ values describing the results of analyses using raw scores *without* age as a covariate since its inclusion did not change the degree of significance of any of the results. Potential gender differences were evaluated and ruled out using independent samples *t*-tests with alpha set at $\alpha = .01$ to reduce the potential for making Type I errors arising from multiple comparisons. All *t*-tests were non-significant, indicating boys and girls in each group performed comparably.

Scale scores can be calculated for each half of the Auditory Attention and Response Set subtest, enabling a comparison of sustained and shifting auditory attention. An examination of each half of the Auditory Attention and Response Set subtest was accomplished by calculating a repeated measures ANOVA, using mean scale scores. There was a main effect for the task, $F(1, 56) = 17.69, p < .001, \eta_p^2 = .24$, suggesting children in both groups found the shifting attention portion of the subtest (i.e. Response Set task) more difficult than the simple sustained attention portion (i.e. Attention Task). However, there was no interaction between task and group, $F(1, 56) = 0.186, p = .67, \eta_p^2 = .003$, suggesting the increased difficulty of the shifting attention task was equally apparent in both groups.

Table 4.1

*Domain and subtest means and standard deviations of FASD and control groups*

| | FASD | | Control | | | |
|---|---|---|---|---|---|---|
| Subtest/domain | *M* | *SD* | *M* | *SD* | *F* | $\eta_p^2$ |
| Domain | 86.62 | 14.46 | 110.45 | 10.24 | 51.02* | .48 |
| Tower | 8.83 | 3.71 | 12.52 | 2.23 | 27.66* | .33 |
| Auditory Attention and Response Set | 6.79 | 2.96 | 9.97 | 1.05 | 29.05* | .34 |
| Visual Attention | 9.07 | 2.37 | 11.59 | 2.92 | 16.26* | .23 |

*Note.* *M* and *SD* describe standard and scale scores whereas *F* and $\eta_p^2$ are derived from analyses of raw scores.

** $p < .001$

## *Error Score Pattern Analyses*

### *Evaluating Impulsivity*

The children with FASD demonstrated more impulsivity than children in the control group on the planning (Tower) task by committing more rule violations, $F(1, 57) = 18.92, p < .001, \eta_p^2 = .41$. In addition, more children with FASD committed rule violations at developmentally inappropriate levels than children in the control group, $\chi^2(1, N = 58) = 53.70, p < .001$. The proportion of children in each group in each developmental classification for rule violations can be viewed in Figure 4.1.

On the simple sustained attention portion of the Auditory Attention and Response Set subtest, the children with FASD did not commit significantly more errors of commission than the children in the control group, $F(1, 57) = 2.75$, *ns*, $\eta_p^2 = .09$, however, significantly more children with FASD fell into the developmentally inappropriate category for errors of commission compared to children in the control group, $\chi^2(1, N = 58) = 26.32, p < .001$ (see Figure 4.2). An examination of the scatterplot of raw frequencies of errors revealed one child in the control group committed a considerably high number of errors of commission and could be considered an outlier. When the ANOVA was recalculated without this participant, it revealed significant between-group differences, $F(2, 56) = 4.87, p = .01, \eta_p^2 = .15$.

An examination of errors of commission on the shifting attention portion (Response Set) of the Auditory Attention and Response Set subtest revealed pronounced between-group differences. The children with FASD committed significantly more errors of commission on this task, $F(1, 57) = 12.35, p < .001, \eta_p^2 = .31$, and significantly more children were described as committing developmentally inappropriate errors of

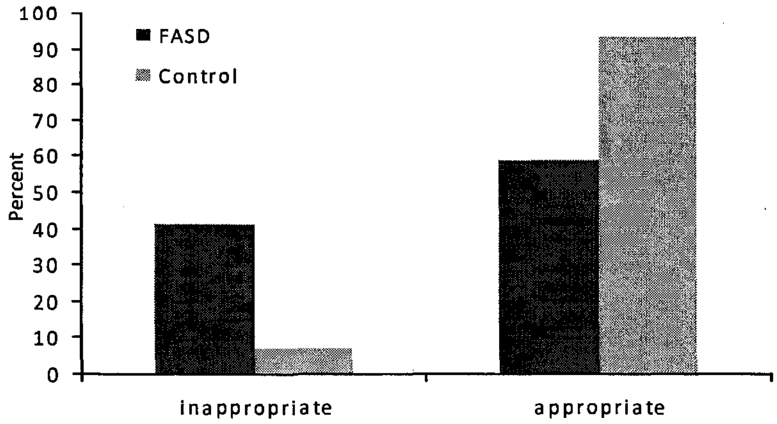


*Figure 4.1.* Percent of children in each group committing developmentally appropriate and inappropriate rule violations on the Tower subtest.

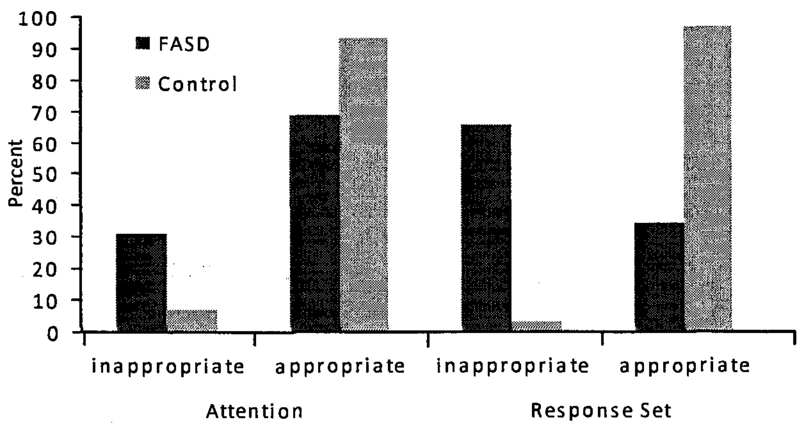


*Figure 4.2.* Percent of children in each group committing developmentally appropriate and inappropriate errors of commission on the Auditory Attention and Response Set subtest.

commission compared to children in the control group, $\chi^2(1, N = 58) = 335.57, p < .001$ (see Figure 4.2).

The children with FASD committed significantly more errors of commission than the children in the control group on the simpler sustained attention (Cats) portion of the Visual Attention subtest, $F(1, 57) = 3.51, p = .04, \eta_p^2 = .11$; however, no child in either group committed more than one such error. Specifically, three children with FASD committed one error of commission. The proportion of children in each group committing developmentally inappropriate errors of commission were similar, $\chi^2(1, N = 58) = 2.15$, *ns*. The proportion of children in each group committing developmentally inappropriate and appropriate errors of commission on the Visual Attention subset can be viewed in Table 4.3. Different results may have been obtained by the ANOVA and chi-square tests because non-parametric tests are generally less powerful than parametric tests (Jackson, 2006). In addition, since no children in either group committed more than one error on this portion of the subtest, the task itself may have been too easy to accurately distinguish between children with FASD and unaffected children. On the more complex shifting attention (Faces) portion of the Visual Attention subtest, the children in each group committed similar raw numbers of errors of commission, $F(1, 57) = 1.54$, *ns*, $\eta_p^2 = .05$, and their errors were classified as developmentally inappropriate equally often, $\chi^2(1, N = 58) = .16$, *ns*.

*Evaluating Inattention*

The children with FASD demonstrated higher levels of inattention compared to the control group on both the sustained and the shifting attention portions of the Auditory Attention and Response Set Subtest (see Figure 4.4). On the sustained attention task, the

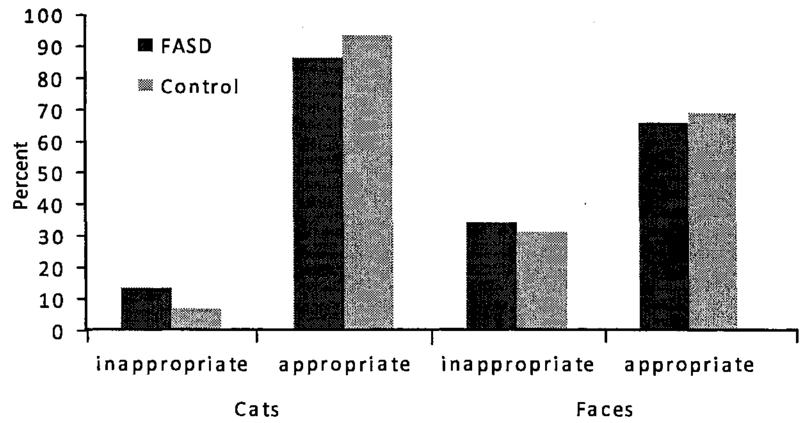


*Figure 4.3.* Percent of children in each group committing developmentally appropriate and inappropriate errors of commission on the Visual Attention subtest.

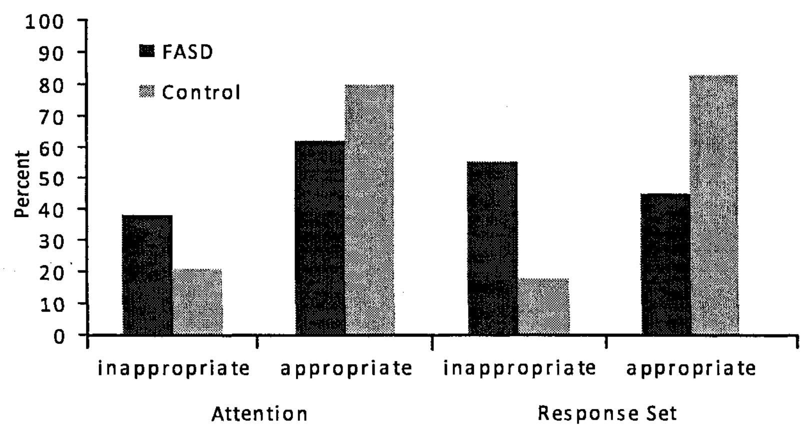


*Figure 4.4.* Percent of children in each group committing developmentally appropriate and inappropriate errors of omission on the Auditory Attention and Response Set subtest.

children with FASD committed more raw numbers of errors of omission than the children in the control group, $F(1, 57) = 5.25, p = .008, \eta_p^2 = .16$, and their errors were more frequently classified as developmentally inappropriate, $\chi^2(1, N = 58) = 5.25, p = .02$ (see Figure 4.4). Group differences were similar with respect to the shifting attention portion of the subtest, $F(1, 57) = 12.35, p < .001, \eta_p^2 = .31, \chi^2(1, N = 58) = 29.24, p < .001$.

On the sustained attention portion of the Visual Attention subtest, the children with FASD were comparable to the children in the control group with respect to raw numbers of errors of omission, $F(1, 57) = 2.29$, *ns*, $\eta_p^2 = .08$. However, significantly more children with FASD were classified as making developmentally inappropriate errors of omission on this task compared to children in the control group, $\chi^2(1, N = 58) = 11.84, p = .001$ (see Figure 4.5). An examination of the scatterplot revealed one child in the control group committed considerably more errors of omission on this task compared to the other children in the group, representing an outlier that affected the significance of the ANOVA; when it was recalculated without the child's data, it revealed a significant between-group difference, $F(2, 56) = 4.26, p = .02, \eta_p^2 = .14$. The children with FASD also committed significantly more errors of omission on the shifting attention portion of the Visual Attention subtest relative to children in the control group, $F(1, 57) = 13.69, p < .001, \eta_p^2 = .33$, and their errors were more frequently classified as developmentally inappropriate, $\chi^2(1, N = 58) = 7.25, p = .007$ (see Figure 4.5).

*Summary*

The children with FASD in this study performed more poorly than typically-developing children on the NEPSY subtests measuring planning, set-shifting, organized search skills, and sustained and shifting attention. In addition, children in both groups

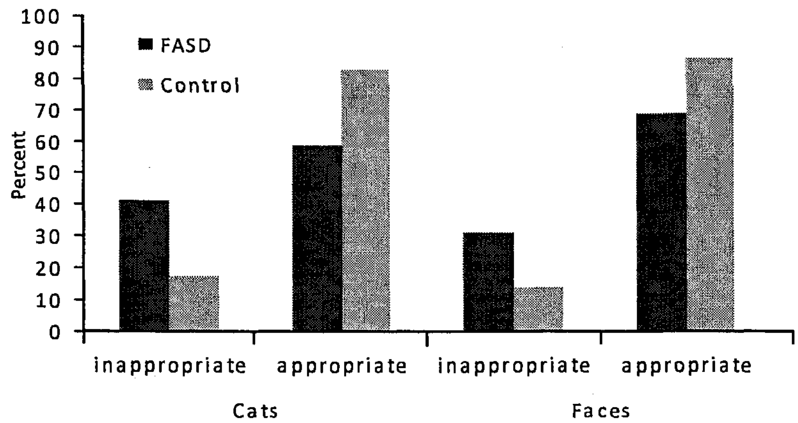


*Figure 4.5.* Percent of children in each group committing developmentally appropriate and inappropriate errors of omission on the Visual Attention subtest.

found shifting auditory attention more difficult than sustained auditory attention. Error score pattern analyses suggest the children with FASD in this study have diffuse deficits in attention and impulse-control, as measured by rule violations and errors of omission and commission. An interesting exception was children with FASD demonstrated similar levels of impulsivity as controls on both parts of the Visual Attention subtest.

The above results suggest the three core subtests of the Attention and Executive Functions domain of the NEPSY are useful in distinguishing children with FASD from children who have not been exposed to alcohol prenatally and who are free of other common neurological risk factors. In addition, error scores can be clinically useful in determining the extent to which the performance of children with FASD is affected by deficits in attention and impulse-control. While the children with FASD in this study appeared to be able to control their impulses on visual attention tasks, they had considerable difficulty controlling their impulses on the planning and auditory attention tasks, and demonstrated global deficits in attention across all tasks.

# CHAPTER FIVE

## Discussion

Arguably the most devastating outcome of exposure to alcohol in utero is damage to the CNS, which is related to lifelong cognitive and behavioural deficits. Recent research has focused on the executive functioning and attention skills of individuals exposed to alcohol prenatally. The deficits in executive functioning and attention experienced by individuals with FASD can be substantial, and may be related to secondary disabilities such as difficulty in school and at work, trouble with the law, and delays in life skills (e.g. Carmichael Olson et al., 1997; Connor, Sampson, Streissguth, Bookstein, & Barr, 2006). The present study aimed to provide information about the clinical utility of the Attention and Executive Functions domain of the NEPSY. Clinical assessment leading to accurate diagnoses of individuals exposed to alcohol prenatally depends upon the availability of psychometrically sound instruments. The NEPSY is a comprehensive battery intended for the assessment of neuropsychological functioning of both younger and older children. Previous research has identified children with FASD and prenatal alcohol exposure demonstrate deficits in planning and organization, set-shifting, and sustained and shifting attention (e.g. Connor et al., 1999; Kerns et al., 1997; Kodituwakku et al., 1995; Korkman et al., 2003; Mattson et al., 1999). However, very little research has examined the use of the NEPSY with this population. In the present study, group differences were observed at the domain and subtest levels and error scores pattern analyses were used to describe whether children with FASD approach tasks differently than non-exposed children.

One of the hallmarks of the NEPSY is it was designed for flexible administration by clinicians. Using this approach, the three core subtests of the Attention and Executive Functions domain were administered to 58 children with and without FASD who were paired and matched for age and gender. Between-group comparisons of the domain and subtest scores found that the children with FASD consistently achieved significantly lower scores than non-exposed children. In other words, the children with FASD struggled considerably more than children in the control group with tasks assessing planning, visual organization, set-shifting, and a number of facets of attention (specifically sustained and shifting attention). These findings are congruent with NEPSY results of a group of children with prenatal alcohol exposure reported by Korkman and colleagues (2003), as well as results from other studies using tasks that assess planning, set-shifting, organization, and attention (e.g. Connor et al., 1999; Kodituwakku et al., 1995; Kodituwakku et al., 2001; Mattson et al., 1999). Interestingly, the FASD group's mean scores on the Tower and Visual Attention subtests were in the average range, so compared to the test norms, they likely would not have been identified as showing deficits in these areas. Since the NEPSY was standardized in the United States over a decade ago, the norms probably do not reflect the current Canadian population, and may not be adequate for the assessment of Canadian children. Whereas having a local norm group is ideal, it is rarely a practical or realistic endeavour for clinicians. Future research might be directed at examining the appropriateness of the new NEPSY-II norms with Canadian children.

Because the Auditory Attention and Response Set subtest yields a score for each half of the subtest, it was further analyzed to determine whether the children with FASD struggled more with shifting versus sustained auditory attention. Whereas the children in both groups performed significantly worse on the shifting attention portion of the subtest, there was not a significant interaction between task and group, suggesting the children with FASD did not struggle considerably more than children in the control group with shifting auditory attention. The shifting attention portion of the subtest is more complex than the sustained attention portion because the child is required to hold more than one instruction in working memory, and respond to more than one stimulus. The present results suggest that the relationship between task complexity and performance holds true not only for children with FASD, but for unexposed children as well.

Because executive functions are thought to be enabled by the coordination of more basic cognitive processes, an analysis of impulsivity and inattention was included in an attempt to describe how the children in each group approached and executed each subtest. Specifically, rule violations on the Tower subtest and errors of commission on the Auditory Attention and Response Set and Visual Attention subtests have traditionally been taken as measures of impulsivity, whereas errors of omission on both of the attention subtests have been used as measures of inattention in other research. The present analyses revealed that the children with FASD demonstrated significantly greater difficulty with inhibition than children in the control group by committing higher rates of rule violations on the Tower subtest. Informal analyses of the protocols belonging to children with FASD and anecdotal reports indicate many children commit the same rule violations repeatedly on the same items on this subtest (J. R. Pei, personal communication, April 30, 2008). While rule violations certainly could be a result of impulsivity, as children are instructed to solve the problem as quickly as they can, the nature of their errors suggest there could be alternative explanations. Luria (1973) described the frontal lobes as the tertiary zones of the motor cortex, and outlined how damage to the lateral areas of the frontal lobes could result in motor perseverations in addition to disturbances in goal-directed behaviour (i.e. executive functions). Kodituwakku (1995; 2001) has also discussed perseverative behaviour as resulting from processing deficits, arguing the dorsolateral prefrontal cortex may be compromised by prenatal exposure to alcohol, leading to inappropriately perseverative behaviour. Given each rule violation on the Tower subtest is immediately followed by examiner feedback for the child to try again without breaking the rules, and given previous research finding perseverative responses on other executive function tasks (e.g. Kodituwakku et al., 1995), the present finding could be interpreted as a problem with cognitive rigidity, or as a problem of impulsivity, which future research employing qualitative analyses of protocols may be able to disentangle.

More children with FASD committed developmentally-inappropriate numbers of errors of commission on both the sustained and shifting attention portions of the Auditory Attention and Response Set subtest compared to the non-exposed children. However, the children in each group did not differ in their levels of impulsivity on either portion of the Visual Attention subtest. Errors of commission on the Auditory Attention and Response Set subtest may pose similar challenges to interpretation as rule violations, given the nature of the tasks. On this subtest stimuli (words) are presented as a brisk rate of one per second. Children who quickly respond to non-target words can certainly be described as impulsive. However, anecdotal reports describe a pattern of performance by children with FASD suggestive of slow processing; some children with FASD respond to target words so slowly that their responses are coded as errors of commission. Kodituwakku (2001) previously suggested deficient processing speed as a potential explanation for perseverative or commission errors, and future research examining the protocols of children with FASD may reveal whether this is the case on the NEPSY.

Similar error patterns were observed when errors of omission were analyzed. The children with FASD demonstrated more lapses in attention than children in the control group by committing significantly more errors of omission on both parts of the Auditory Attention and Response Set subtest. The children with FASD also demonstrated more inattentiveness than the children in the control group on both portions of the Visual Attention subtest, however, by committing more errors of omission.

*Clinical Implications*

Taken together the error score pattern findings suggest children with FASD experience more lapses in attention on structured sustained and shifting attention tasks compared to non-exposed children. In contrast, errors of commission on the NEPSY have proven more difficult to interpret, and more detailed evaluations of test protocols belonging to children with FASD may elucidate whether errors of commission on the Auditory Attention and Response Set and Visual Attention subtests, as well as rule violations on the Tower subtest are manifestations of deficits in processing speed, or of cognitive rigidity rather than impulsivity.

The results of the error score pattern analyses provide insight into strategies that may work for children with FASD. Individuals in this population may perform and learn better when presented with tasks where they control the rate of presentation, facilitating efficient processing. Similarly, tasks should be broken down to reduce their complexity and in such a way that reduces the amount of information or number of instructions given to the child at one time. There is extensive evidence that planning tasks are difficult for children with FASD, and these children seem to struggle with impulsivity, and/or perseverative, rigid thinking. Telling a child with FASD that he or she is making a mistake or approaching a problem in the wrong way may not be sufficient in changing his or her approach; children with FASD seem to need step-by-step guidance and prompting when learning how to solve new problems. When children with FASD persistently make the same mistakes despite corrective feedback, results suggest they *can't* change the way they are thinking about the problems, rather than indicating they are engaging in stubborn or oppositional behaviour. Future research employing planning tasks could take error score pattern analyses one step further and tally the number of times each examinee makes the same errors on the same items. The children with FASD in this study struggled with all of the tasks presented to them, but seemed to struggle less with impulsivity on visual attention tasks, potentially because the target stimuli were constantly displayed for the children to refer back to. Teaching children with FASD to check visual presentations or scripts outlining what they are supposed to do (and in what order) may help to reduce every-day occurrences of impulsive behaviour.

Discussed previously, inhibition and working memory are thought to underlie executive functions (Welsh, 2002). There is preliminary evidence that interventions aimed at improving working memory may be effective in improving attention in adults with mild traumatic brain injury (Cicerone, 2002), which may hold promise for interventions with individuals with FASD. Specifically, activities that activate and burden working memory, such as dual-task activities may be avenues of intervention for improving attention and executive functioning.

*Theoretical Implications*

Luria's theory of dynamic functional systems described how the complex and interdependent relationships between regions and structures of the brain produces complex cognitive and behaviour. Children with FASD display a range of deficits indicative of disruptions in the third functional unit, but most children seem to lack the profound disturbances found in individuals with focal damage to the frontal lobes. Luria described problems with voluntary attention, memory, and executive functions (which he described as regulated, goal-directed behaviour) as a result of lesions to the frontal lobes and/or their connections with other parts of the brain. The children in this study demonstrated global deficits in planning, organization, set-shifting and attention on three subtests from the NESPY, suggestive of brain damage in the frontal lobes, their functional connections with other regions of the brain, and/or subcortical structures that the frontal lobes both depend on and regulate.

Diffusion Tensor Imaging (DTI) is a relatively new neuroimaging tool that is used to assess the integrity of axonal routes in the brain, and can be used to determine whether damage to the functional connections between structures in the brain are responsible for cognitive and behavioural deficits in individuals with FASD. Lebel and her colleagues (in press) have used DTI with children with FASD and found diffusion abnormalities in a number of white matter tracts, and in three structures functionally connected to the frontal lobes (the globus pallidus, the putamen, and the thalamus). Further research examining specific regions of the brain may further support or refute Luria's theory of dynamic functional systems.

*Strengths and Limitations*

When compared to previous studies that have examined individuals with prenatal alcohol exposure without accounting for differences in diagnoses, a strength of the present study was the careful selection of children diagnosed with an FASD, following the DPN Four Digit Code (Astley, 2004) and the Canadian Medical Association's guidelines (Chudley et al., 2005). In order to meet these diagnostic criteria, each child was determined to have either neurobehavioural disorder (alcohol exposed), or static encephalopathy (alcohol exposed). Patients referred to the Glenrose Rehabilitation Hospital's FASD Clinic must have confirmed prenatal alcohol exposure prior to being eligible for assessment and diagnosis, and approximately 60% of all children referred obtain a diagnosis (J. R. Pei, personal communication, April 30, 2008). Because prenatal alcohol exposure leads to a diagnosis of an FASD less than one hundred percent of the time, it is possible some participants in other studies did not meet the diagnostic criteria of having an FASD, despite heavy prenatal alcohol exposure. Another strength of this research is the inclusion of a control group that was matched to the experimental group for age and gender. Matching greatly reduced the likelihood of error variance introduced by these two variables, and increased the probability of obtaining meaningful and interpretable results.

Limitations of the current study included the drawback of using archival data and the inability to collect additional demographic information. Variables such as socioeconomic status and history of involvement of child welfare services are important because they can provide an indication of social (home life) stability and exposure to extracurricular learning opportunities; there may be substantial differences between the participants in each group in regards to social stability and enriched learning opportunities. Ethnicity, IQ, and information about the amount of alcohol exposure were also not included in the archival data, and were impossible to match the groups on. Finally, it is known that there are specific developmental trajectories for executive functions, and other literature suggests the most rapid increase in the development of many of these functions occurs between the ages of 6 and 9 (Garon et al., 2008; Welsh, 2002). The participants in each group ranged in age from 6 to 11 years old, which is a wide age range; unfortunately the sample size was not adequate for a comparison of older and younger children.

*Conclusion*

The NEPSY is ideal for clinical use because it provides a comprehensive measure of neuropsychological functioning, and is designed to be administered in a flexible manner. Using this approach, clinicians can take into consideration their specific hypotheses regarding the referral questions and tailor administration of the NEPSY accordingly. The present study supports the use of the Attention and Executive Functions domain of the NEPSY with children suspected of having an FASD, but with a cautionary note. The children with FASD did not obtain a low enough mean score on two of the three subtests administered to be considered impaired in comparison to the test norms, even though they showed significant deficits compared to the control group. Despite achieving a group mean score in the average range on these subtests, many of the children with FASD achieved below-average scores however. The scope of this study did not permit me to analyze whether the children with FASD who achieved average scores on these subtests would also achieve average scores on other measures of the same skills. It is possible the NEPSY norms for the three subtests included in this study are not representative of Canadian children, as they are over a decade old; future research may examine the appropriateness of the NEPSY –II norms.

The motivation to conduct this study came from extensive experience working with children and youth exposed to alcohol prenatally, and watching many of them struggle with the basics of daily living and self-care. The children with FASD in this study demonstrated significant deficits in aspects of executive functioning and attention as measured by the NEPSY. However, an assessment of the everyday manifestations of these deficits was not obtained, mirroring other research that has also stopped short of describing the day-to-day struggles of children with FASD. A logical hypothesis is that executive functioning is related to daily living and adaptive behaviour throughout the lifespan, and future research may elucidate whether or not this relationship exists.

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