Executive Function in Adolescents with Fetal Alcohol Spectrum Disorders:

A Developmental Perspective

by

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Declaration

I, Tania Pomario, hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise), and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

_____ 11/09/2024

Tania Pomario Date

Abstract

Objective: Children with fetal alcohol spectrum disorders (FASD) have well-documented deficits in executive function. However, few previous studies have examined executive deficits displayed by children with FASD within a developmental framework. This longitudinal study explored the manifestation of executive function in both alcohol-exposed and typically developing adolescents from a low socioeconomic community in a low-and middle-income country. **Method:** 110 participants (48 with FASD, mean age 14.65 years, SD = 0.65 and 62 controls, mean age 14.49 years, SD = 0.44) were assessed at two time points, 18 months apart. Participants completed a battery of neuropsychological tests to measure executive function. Parents and teachers provided ratings of participants' everyday executive function on the Behavior Inventory of Executive Function (BRIEF). Principal component analysis examined the underlying components of the neuropsychological measures of executive function in the control group. Composite executive function test scores were computed for both groups, and ANCOVA was used to examine whether a) cognitive performance of the FASD group differed from that of the control group, and b) whether there was a change in scores across the two time points. Chi-square and ANCOVA analyses assessed group differences on the BRIEF. Finally, correlations and regressions investigated whether composite cognitive scores were significant predictors of behaviour, as measured by the BRIEF. **Results:** Neuropsychological measures of executive function clustered into four distinct factors reflecting the domains of Generativity, Attentional Control, Working Memory, and Processing Speed. The FASD group performed significantly worse than the control group on the Working Memory domain ($p < .01$). On the BRIEF, a significantly higher proportion of the FASD group was rated as having scores in the clinically impaired range by both parents ($p < .001$) and teachers ($p < .01$) compared to controls. Significant differences were found between the FASD and control groups on the Emotional Control and

Organization of Materials scales of the BRIEF Teacher. Significant differences were found for the Global Executive Composite and the Plan/Organize and Monitor scales on the BRIEF Parent. The cognitive composites Attentional Control and Generativity were significantly negatively correlated with scores on several of the BRIEF Teacher clinical scales for the FASD group. **Conclusion:** Performance on working memory tasks emerged as the only domain of executive function that distinguished the FASD group from the control group. There was no notable developmental change in executive abilities over the course of the 18-month period in either group. Both parents and teachers reported that the FASD group displayed significantly more executive deficits, but only teacher ratings were correlated with neuropsychological test results. This suggests that children with FASD have more difficulties with executive functioning in their everyday lives than what is being detected on neuropsychological measures alone.

Keywords: fetal alcohol spectrum disorder, executive function, Behavior Rating Inventory of Executive Function, adolescents, longitudinal study

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Abbreviations

AB tasks	A-not-B tasks
ADHD	Attention Deficit Hyperactivity Disorder
ARBD	Alcohol-related birth defects
ARND	Alcohol-related neurodevelopmental disorder
BRI	Behavioral Regulation Index
BRIEF	Behavior Inventory of Executive Function
CANTAB	Cambridge Neuropsychological Test Automated Battery
CIFASD	Collaborative Initiative on Fetal Alcohol Spectrum Disorders
CNS	Central nervous system
CPT-II	Connors' Continues Performance Test – Second Edition
CRT	Choice Reaction Time
DET	Department of Education and Training
D-KEFS	Delis-Kaplan Executive System
DR	Delayed Response
DTI	Diffusion tensor imaging
EFA	Exploratory factor analytic
FAS	Fetal Alcohol Syndrome
FASD	Fetal Alcohol Spectrum Disorders
GEC	Global Executive Composite
ID/ED	Intradimensional/Extradimensional Set-Shifting
IQ	Intelligence Quotient
K-ABC	Kaufman Assessment Battery for Children
LMIC	Low-and-middle-income country

MFFT	Matching Familiar Figures Test
MI	Metacognition Index
MHIC	Middle- and high-income country
MRI	Magnetic resonance imaging
NEPSY	A Developmental NEuroPSYchological Assessment
NIAAA	National Institute of Alcoholism and Alcohol Abuse
NIH	National Institutes of Health
PCA	Principal Component Analysis
PAE	Prenatal alcohol exposure
pFAS	partial FAS
PIRLS	Progress in International Reading Literacy Study
SES	Socioeconomic status
SRT	Simple Reaction Time
SWM	Spatial Working Memory
TMT-A	Trail Making Test Part A
TMT-B	Trail Making Test Part B
TOH	Tower of Hanoi
TOL	Tower of London
WCST	Wisconsin Card Sorting Test

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Chapter One: Introduction

Background

This dissertation explores the relationship between Fetal Alcohol Spectrum Disorders (FASD) and the development of executive functioning during adolescence. It aims to compare the development of executive function in adolescents with FASD with that of typically developing adolescents from a low socioeconomic status (SES) community in South Africa across two points in time. Although deficits in executive function following prenatal alcohol exposure (PAE) are well-established, few studies have situated their findings within a developmental framework. This is problematic, as executive function is not only a complex construct with multiple inter-related and inter-dependent domains that function together as a supervisory system (Anderson, 2002), but also displays a protracted period of development, only reaching maturity by early adulthood (Anderson, 2008).

Rationale

The most commonly used approach to study the cognitive profiles of children with FASD is the individual- or group-matching methodology (Kodituwakku, 2009). A limitation of this approach is that it does not allow for an understanding of developmental trajectories (Kodituwakku, 2009). Furthermore, many studies in the field have used large age ranges (usually 8 to 18 years) and have often not made age-related comparisons. This longitudinal study aims to address the fact that very little is known about the developmental trajectory of executive function in children with FASD. To the best of my knowledge, this is the first longitudinal study to examine executive function in adolescents with FASD. A better understanding of how executive function develops during adolescence in individuals with

FASD would facilitate greater accuracy in diagnosing FASD at different developmental stages.

Children's performance on measures of executive function appears to be influenced by a variety of factors, including general intellectual ability (Friedman et al., 2006) and socioeconomic variables such as parental level of education (Ardila et al., 2005; Hackman et al., 2015; Rhoades et al., 2011). Findings from a Canadian study, which indicate that Aboriginal and Caucasian children with FASD exhibit different patterns of strengths and weaknesses in neurobehavioural functioning (Rasmussen et al., 2006), also raise the possibility that cultural factors may influence the cognitive profiles obtained in diverse samples. The 'executive profile' of this sample of adolescents from a low SES community in a low-and-middle-income country (LMIC) may therefore be very different from that of adolescents from middle- and high-income countries (MHICs). It is imperative to obtain knowledge about the neurobehavioural problems displayed by South African adolescents with FASD, as data obtained from cohorts in MHICs may not necessarily be applicable to the local context, in which confounding factors associated with low socioeconomic circumstances prevail.

Individuals with FASD demonstrate both primary disabilities, in the form of cognitive difficulties and behavioural disturbances, and secondary disabilities, such as mental health concerns, involvement in the criminal justice system, and substance abuse (Landgren et al., 2019; Larkby et al., 2011; Mela et al., 2020; Streissguth et al., 2004; Welch-Carre, 2005). A better understanding of how executive function develops during adolescence in individuals with FASD will in turn allow for the development of appropriate intervention strategies to address the specific needs of this vulnerable population, including the amelioration of primary disabilities and prevention of secondary disabilities.

Thesis Outline

Chapter 2 provides a review of the relevant literature in the field to contextualise the proposed investigations. Chapter 3 describes the study's aims and objectives. Chapter 4 reports the research design and methods employed in this study. Chapter 5 describes the sample characteristics and reports the results of the statistical analyses. In Chapter 6, the main findings of the study and how they relate to previous studies in the field are discussed. This chapter also discusses the limitations of this study and directions for future research.

Chapter Two: Literature Review

Introduction

In this chapter, I first define various key concepts in the diagnosis and classification of fetal alcohol spectrum disorder (FASD). I will then provide information on the prevalence of FASD, focusing specifically on the studies conducted in South Africa. The following sections provide a detailed overview of the relevant literature in this area. I will begin by examining theories of executive function, discuss issues around the measurement of executive function, and then describe the typical development of this domain of cognitive function during childhood and adolescence, linking it with what we know about brain development during this period. I will then review the literature on the effects of prenatal alcohol exposure (PAE) on executive function in children and adolescents, explore some of the factors that influence the relationship between FASD and executive function deficits, and discuss how the findings of previous studies in the field relate to our current understanding of brain-behaviour relationships.

Defining FASD

Alcohol is a potent teratogen that can easily cross the placenta, leading to a range of adverse outcomes including stillbirth, premature birth, intrauterine growth retardation, and low birth weight (Popova et al., 2021). It is now well established that PAE can cause alterations in the developing brain (Donald et al., 2015) and, consequently, deficits in cognitive function and behavioural difficulties (Mattson et al., 2019; Riley & McGee, 2005).

In its most severe form, PAE causes fetal alcohol syndrome (FAS), a complex neurodevelopmental disorder defined by four criteria: a history of alcohol exposure during pregnancy, pre-and/or postnatal growth retardation, a characteristic pattern of facial

abnormalities, central nervous system (CNS) dysfunction that may take the form of gross structural brain abnormalities, neurological soft signs, recurrent non-febrile seizures, small head circumference, and behavioural difficulties (Hoyme et al., 2016; Hoyme et al., 2005; Riley & McGee, 2005; Stratton et al., 1996). Because the effects of PAE vary depending on the dose and duration of exposure (Flak et al., 2014), the American Institute of Medicine created a five-category classification system to account for the range of outcomes linked to PAE. This classification system uses the terms fetal alcohol syndrome (FAS) with and without confirmed maternal alcohol exposure, partial FAS (pFAS), alcohol-related birth defects (ARBD) and alcohol-related neurodevelopmental disorder (ARND) (Stratton et al., 1996). This classification system was refined by Hoyme et al. in 2005 and again in 2016 to set the specific parameters for each diagnostic category (Hoyme et al., 2016; Hoyme et al., 2005). Individuals with pFAS have some, but not all, characteristics of FAS, and have confirmed prenatal alcohol exposure. The diagnosis of ARBD requires evidence of CNS neurodevelopmental abnormalities and/or a complex pattern of behavioural or cognitive abnormalities, and confirmed prenatal alcohol exposure. An ARND diagnosis requires one or more congenital anomalies (which may include malformations of the cardiac, skeletal, renal, visual, or auditory systems) and confirmed prenatal alcohol exposure.

The term fetal alcohol spectrum disorder (FASD) was initially conceptualised as an umbrella term, not a diagnosis, and was used to describe the range of effects associated with PAE (Mattson et al., 2011; Petrelli et al., 2018; Riley & McGee, 2005). However, some diagnostic guidelines, including the Canadian (Cook et al., 2016) and Australian guidelines (Bower & Elliott, 2016), have subsequently advocated the use of FASD as a diagnostic term and collapsed the diagnostic categories outlined above to FASD with sentinel facial features and FASD without sentinel facial features.

Prevalence of FASD

In the United States, the prevalence of FASD in the general population is estimated at approximately 10 per 1,000 births (May & Gossage, 2001). In Europe, a population-based, active case ascertainment study in central Italy found a rate between 4.0 to 12.0 per 1,000 for FAS and between 23.1 and 62.6 per 1,000 for FASD (May et al., 2011). A meta-analysis of 24 unique studies including 1,416 children diagnosed with FASD (age range, 0-16.4 years) found an estimated global prevalence rate of 7.7 per 1,000 (95% CI, 4.9-11.7 per 1,000) (Lange et al., 2017).

Epidemiological studies in South Africa have reported much higher prevalence rates. In the community in the Western Cape Province, from which the sample for the present study was drawn, the rate of FAS and pFAS was documented as 68.0 to 89.2 per 1,000 (May et al., 2007). A later study in the same community documented an overall FASD (FAS, pFAS, and ARND) prevalence rate of 136.1 to 207.5 per 1,000 (May, Blankenship, et al., 2013). In another community in the Western Cape, rates of 89.1 to 129.1 per 1,000 were found for FAS alone. These rates increased to 196 to 275.5 per 1,000 when children with pFAS and ARND were included in the sample (May et al., 2017). The very high prevalence rates of FASD in South Africa are not isolated to the Western Cape. For example, a study in the Northern Cape Province found rates of 93.2 to 149.9 per 1,000 in one community and 61.0 to 90.3 per 1,000 in another (Urban et al., 2008). Overall, a meta-analysis conducted by Lange et al. (2017) estimated the prevalence of FASD in South Africa to be 111.1 per 1,000. These are some of the highest prevalence rates in the world (Lange et al., 2017; May et al., 2007) and are concerning, given that FASD leads to a significant degree of disability and is entirely preventable (Rasmussen, 2005).

Although not yet completely understood, the reasons for South Africa's high burden of FASD appear to be related to a pattern of maternal alcohol consumption characterised by frequent binge drinking throughout pregnancy (May et al., 2017). Furthermore, demographic factors (such as rural residence, low socioeconomic status, and low levels of maternal education) and maternal physical characteristics (such as low weight and short stature) appear to play a significant role in the extent of neurobehavioural problems experienced by children with FASD in this population(May, Tabachnick, et al., 2013).

Cognitive and Behavioural Deficits Associated with FASD

In addition to lower IQ scores (Carter et al., 2016; Ferreira & Cruz, 2017; Mattson et al., 2011; Mattson et al., 1997), children with FASD exhibit impairments in several specific domains of cognitive function, including language, motor function, attention, memory, and visuospatial function, and often exhibit poor academic performance (Adnams et al., 2001; Coles et al., 2002; Korkman et al., 2003; Mattson et al., 2019; Mattson et al., 1998; Uecker & Nadel, 1996). Behaviourally, children with FASD are often described as hyperactive, impulsive, and distractible (Mattson & Riley, 2000; Tsang et al., 2016).

Deficits in executive function following PAE have garnered particular interest because such deficits could possibly explain some of the behavioural problems exhibited by children with FASD (Kodituwakku, Kalberg, et al., 2001). Whilst the presence of deficits in executive function as a consequence of PAE has been well established in both children and adolescents (Mattson et al., 2019), few studies have located their findings within a developmental framework (Rasmussen, 2005). This is problematic because, as discussed in detail below, executive function develops throughout childhood and adolescence and reaches maturity only in early adulthood (Anderson, 2002; V. A. Anderson et al., 2008; De Luca & Leventer, 2008).

Conceptualizing Executive Function in a Developmental Context

Executive function has been defined as "an umbrella term that incorporates a collection of inter-related processes responsible for purposeful, goal-directed behavior" (Anderson, 2002, p. 71). These processes play an important role in cognitive function and support the regulation of behaviour, emotions, and social interactions (Anderson, 2002; Anderson et al., 1999). Executive dysfunction is associated with a variety of deficits, such as difficulties with impulse control, poor self-monitoring, difficulties in planning and organising complex tasks, impaired problem-solving, perseveration, and reduced working memory (Anderson, 2002, 2008; Anderson, Northam, et al., 2001). Executive dysfunction is not exclusive to cognitive processes, but also impacts emotional responses and behaviour. The literature typically dichotomizes processes that constitute executive function into 'cold' or purely cognitive abilities, which are tapped when the individual is faced with abstract decontextualised problems, and 'hot' executive functions, which refer to the aspects of executive function involved in the regulation of emotions and motivation (Anderson, 2008). Although there is some evidence that *hot* executive function is also affected in FASD (Carrick & Hamilton, 2023; Kodituwakku, May, et al., 2001), this dissertation focuses mainly on *cold* executive abilities.

As will be discussed in more detail below, research has shown that children with PAE display impairments in various aspects of executive function, including attentional control (Coles, 2001; Coles et al., 2002; Kodituwakku et al., 1995), inhibition (Mattson et al., 1999; Noland et al., 2003), verbal and non-verbal fluency (Kodituwakku et al., 2006; Mattson et al., 1999; Schonfeld et al., 2001) cognitive flexibility (Green et al., 2009; Jacobson, 1998; Kodituwakku et al., 1995; Mattson et al., 1999; Schonfeld et al., 2001), planning and goal setting (Kodituwakku et al., 1995; Kodituwakku, May, et al., 2001; Mattson et al., 1999),

working memory (Kodituwakku et al., 1995; Moore et al., 2021; Olson et al., 1998), and information processing (Burden et al., 2005; Jacobson et al., 1993). However, few studies have firmly placed their findings within a theoretical framework of executive function. This is problematic because the assessment of executive function is plagued by issues related to both conceptualisation and measurement.

The following section focuses on defining executive function, discussing a developmental model of executive function, and examining some of the difficulties in the measurement of executive function. In addition, I describe the typical development of this domain of cognitive function during childhood and adolescence, linking it with our knowledge of brain development during this period.

Defining Executive Function

Despite advances in the definition and operationalisation of executive function, the construct is still open to debate. Early models of executive function postulated that a single executive is required when performing tasks that entail planning and organisation (Della Sala et al., 1998). However, findings that many tests purportedly measuring executive function are poorly correlated and that patients with focal frontal lesions displayed deficits in some, but not other, aspects of executive function have brought this into question (Della Sala et al., 1998). Subsequently, several factor analytic studies (Brocki & Bohlin, 2004; Levin et al., 1991; Miyake et al., 2000; St Clair-Thompson & Gathercole, 2006; Welsh et al., 1991) identified multiple factors or domains of executive function. Although the number and make up of these factors, as well as their applicability to paediatric populations are still under debate (Lee et al., 2013), modern theories now conceptualise executive function as "multiple process related systems that are inter-related, inter-dependent and function together as an integrated supervisor or control system" (Anderson, 2002, p. 72).

A Theoretical Model of Executive Function

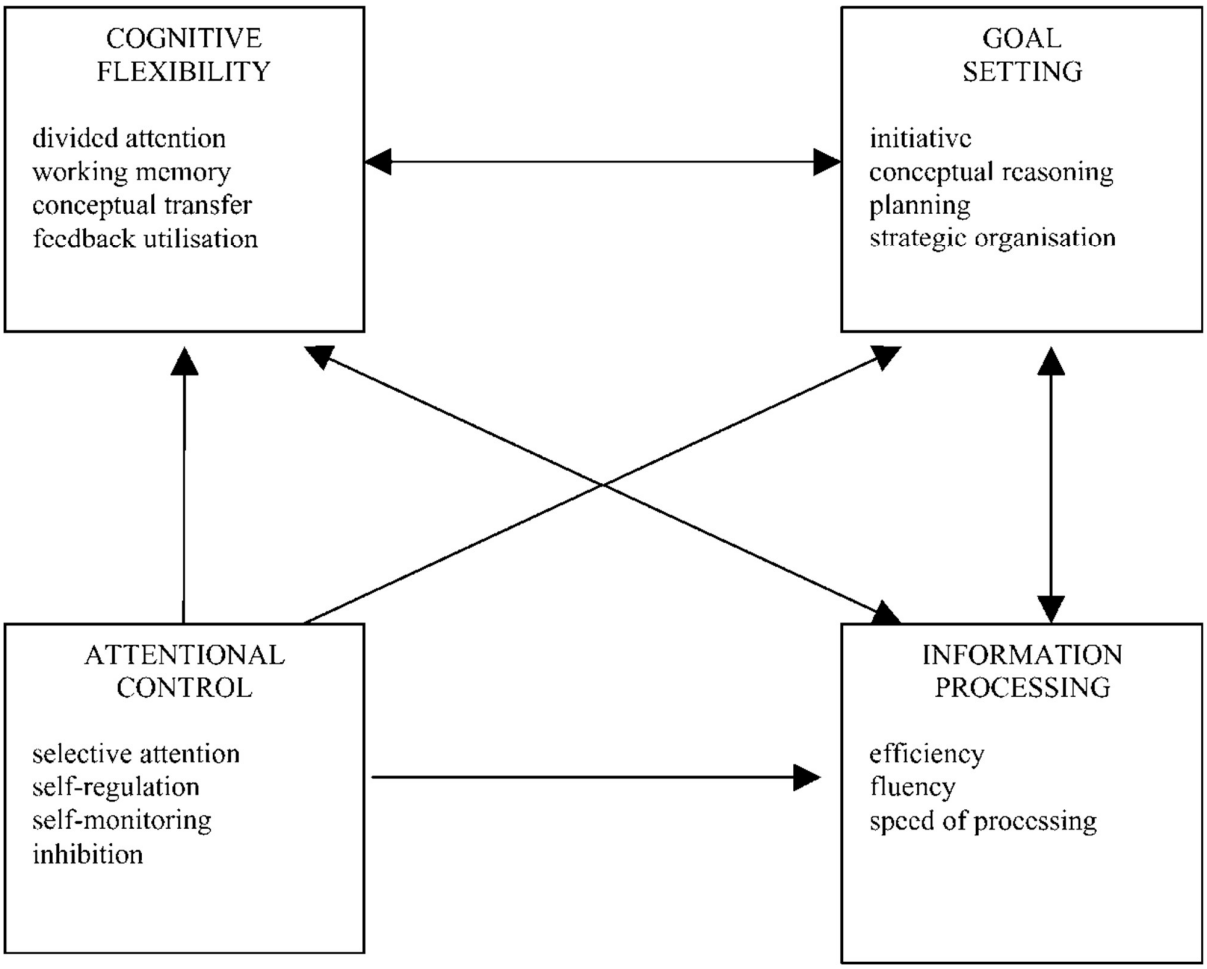
This study used the Executive Control System model proposed by Anderson (2002). Although it can be described more accurately as a conceptual framework rather than a theoretical model (Anderson, 2008), this model is well-suited to developmental research, as it considers evidence (discussed in detail below) that different aspects of executive function appear to mature at different rates (Anderson, 2002).

In this model, executive function comprises four discrete domains: (i) attentional control, (ii) cognitive flexibility, (iii) goal setting, and (iv) information processing (Anderson, 2002, 2008). Although these domains are seen as independent, they interact with one another in a bi-directional manner, with the nature of the task determining the degree of input from each component (see Figure 1).

Anderson (2002) developed his model based on evidence from factor analytic studies that tests of executive function generally load on three to four factors, with similar factors reported across studies, despite variations in the test batteries used. I will now take a more detailed look at these four domains and the evidence that supports them.

Figure 1

Anderson's Executive Control System Model.



Note. From "Assessment and development of executive function (EF) during childhood," by P. Anderson, 2002, *Child Neuropsychology*, *8*(2), p. 73. (https://doi.org/10.1076/chin.8.2.71.8724) Copyright 2002 by Taylor & Francis. Reprinted with permission.

Attentional Control refers to selective and sustained attention and self-monitoring as well as the ability to avoid impulsive errors or engage in automatic (prepotent) responses (Anderson, 2002, 2008). Using principal component analysis (PCA), Levin et al. (1991) analysed seven measures of executive functioning that clearly showed evidence of developmental progression in a sample of 52 children (aged 7- to 15-years). They found that the percentage of conceptual responses on the Wisconsin Card Sorting Test (WCST) and number of false alarms on a Go/No-go task loaded on a factor they termed 'Freedom from Perseveration' '(Levin et al., 1991). In their study of 3- to 28- year-olds (n = 110), Welsh et al. (1991) also used PCA to explore the interrelations among nine executive function measures. They identified a factor called 'Hypothesis Testing/Impulse Control,' made up of scores on the WCST and Matching Familiar Figures Test (MFFT) (Welsh et al., 1991). Lehto et al. (2003) assessed a sample of 8- to 13-year-olds (n = 108) on eight measures of executive functioning. Using exploratory factor analysis (EFA), they identified a factor they termed 'Inhibition, ' made up of scores on the Tower of London (TOL) and MFFT. Brocki and Bohlin (2004) made use of dimensional analysis to investigate the development of executive function in a sample of 92 children (aged 6- to 13-years) on various measures of executive function. In their study, four measures tapping impulsivity and inattention (disinhibited, impulsive, and inattentive-impulsive errors on the Connors Continuous Performance Test (CPT) and commission errors on a Go/No-go task) loaded on a factor they called 'Disinhibition' (Brocki & Bohlin, 2004).

Cognitive flexibility refers to the ability to flexibly switch between response sets, being able to self-correct, and devise alternative strategies to complete complex tasks (Anderson, 2002). The ability to divide attention and temporarily hold information online (i.e. working memory) is an integral component of this domain (Anderson, 2002, 2008). Brocki and Bohlin (2004) found that a digit span test (forward and backward), a verbal fluency task,

a Stroop-like task, the Hand Movement test from the Kaufman Assessment Battery for Children (a measure of non-verbal working memory), and the Time Reproduction task (which measures one's subjective sense of time) all loaded on a factor they termed 'Working Memory/Fluency.' Lehto et al. (2003) found that scores on Part B of the Auditory Attention and Response Set task of the NEPSY, a maze task, and the Spatial Working Memory and Spatial Span tasks of the Cambridge Neuropsychological Test Automated Battery (CANTAB) loaded on a factor they termed 'Working Memory.' However, their EFA also identified a factor they termed 'Shifting,' comprised of scores on the Trail Making Test Part B (TMT-B) and a verbal fluency task (Lehto et al., 2003), which can also be considered as part of Anderson's Cognitive Flexibility domain.

Goal Setting refers to the ability to develop new concepts, plan, and make use of efficient strategies when completing tasks (Anderson, 2002). Welsh et al. (1991) found that two versions of the Tower of Hanoi (TOH), a task generally considered to measure planning and organisation, loaded on a factor they termed 'Planning.' Similarly, Levin et al. (1991) found that performance on the TOL loaded on a factor they termed 'Planning/Strategy.'

Information processing refers to "fluency, efficiency and speed of output" (Anderson, 2002, p. 74). Welsh et al. (1991) found that scores on a semantic fluency task, a visual search task (where children search for a target stimulus embedded in a display of distractors) and a motor sequencing task loaded on a factor they termed 'Fluid and Speeded Response.' Brocki and Bohlin (2004) also identified a factor they termed 'Speed/Arousal.' This factor included response times on a Go/No-go task, response times on the CPT, and omission errors on both tasks. Furthermore, they noted that children with slower response times made more omission errors and hypothesised that this may reflect a deficit in arousal and motivation to meet the

demands of the situation, or a trade-off between speed and accuracy (i.e. an attempt to make fewer commission errors).

Although studies using PCA and EFA, such as those described above, support the contemporary view that executive function comprises distinct domains that operate in an integrative manner to support individuals in completing novel and complex tasks (Anderson, 2002), there are several inconsistencies in the results. For example, tasks such as the TOL and its variant, the TOH, have been found to load both planning (e.g., Levin et al., 1991; Welsh et al., 1991) and inhibition (Lehto et al., 2003) factors. In addition, EFA studies attempting to delineate domains of executive function have been criticised for several reasons, such as often lacking clear theoretical foundations and being data-driven, often being made up of insufficient measures of the same domain to account for the influence of lower-order processes and to allow for measurement of variance attributable to the underlying executive function constructs, and for using complex tasks of executive function, which makes it difficult to isolate the specific skills being assessed (Lee et al., 2013; Miyake et al., 2000).

In an attempt to address these shortcomings, Miyake et al. (2000) used latent variable analysis (i.e. what is shared among multiple tasks purportedly measuring a specific aspect of executive function) to study the organisation of executive functions in a sample of young adults (n = 137). They focussed on three executive functions frequently postulated in the literature, namely: i) 'Shifting' - the ability to shift between tasks or mental sets; ii) 'Updating' - updating and monitoring of working memory representations; and iii) 'Inhibition' - inhibition of prepotent responses (Miyake et al., 2000). Using confirmatory factor analysis, they demonstrated that these three aspects of executive function operate independently but are also related to each other (Miyake et al., 2000). Miyake et al.'s model has subsequently been used in several other studies, including studies with children (see Lee

et al., 2013 for review). Although there is some evidence that the same latent executive factors are present in children as in adults (Lehto et al., 2003; Rose et al., 2011; Wu et al., 2011), other studies have failed to find such differentiation (e.g., Willoughby et al., 2012) or have identified fewer than three factors (e.g., St Clair-Thompson & Gathercole, 2006). Furthermore, there is some evidence that the structure of executive function might vary during development, with a lack of differentiation present during early childhood, a separation into a two-factor structure occurring during middle childhood, followed by the emergence of a three-factor structure during adolescence (Lee et al., 2013).

Miyake et al.'s statistically derived model has been very useful to examine the fractionalisation of executive function in both adults and children. However, it should be noted that Miyake et al. (2000) specifically focused on three relatively circumscribed lower-level functions because they could be operationally defined and measured through relatively simple tasks. This does not mean that Shifting, Updating, and Inhibition are the only aspects of executive function (Miyake et al., 2000). In addition, the relationship between these basic executive functions and more complex concepts (such as planning and conceptual reasoning) remains unclear (Miyake et al., 2000). Finally, several studies (Lee et al., 2013; Lehto et al., 2003; Miyake et al., 2000) have found high intercorrelations between these three basic executive functions, although the source of this commonality remains poorly understood. Miyake et al. (2000) proposed that "controlled attention," a crucial component of working memory, or some sort of inhibitory process might account for the shared variance amongst different executive functions. Other authors (e.g., Lee et al., 2013; Rose et al., 2011) have suggested that processing speed contributes to the efficacy of all executive functions.

A broader conceptual framework, such as that proposed by Anderson (2002), is not inconsistent with Miyake et al.'s model. Miyake et al.'s Inhibition would fall under

Anderson's Attentional Control domain, whilst both Updating and Switching would fall under his Cognitive Flexibility domain. Findings that processing speed accounts for much of the intercorrelations among Miyake et al.'s three basic executive functions (Rose et al., 2011) is consistent with Anderson's view that information processing is not simply an 'ingredient' factor. Although not as well validated as that of Miyake et al., Anderson's conceptual model remains useful because it captures the complexity of executive function.

Assessment of Executive Function

The measurement of executive function in both clinical and research settings is plagued by several difficulties. Executive function skills are elicited in situations characterised by novelty and complexity, and/or where the integration of information is required (Walsh, 1978). Therefore, the structured environment of the research or clinical setting may mask deficits because the examiner inadvertently acts as a form of executive control for the child (Lezak et al., 2012).

In addition, lower-order (i.e. non-executive) processes clearly mediate executive function. Although some measures of executive function are described as being relatively 'pure' tests of this ability, most tests rely to some extent on intact non-executive abilities such as language and visuo-perceptual function (V. A. Anderson et al., 2008). However, there is a great deal of variability in the ability of measures of executive function to isolate the contribution of lower-order skills on performance. Miyake et al. (2000) have thus highlighted the possibility that low correlations among tasks that purport to measure executive function may not necessarily reflect the independence of executive domains but may instead be a manifestation of differences in the non-executive (e.g., language, visuo-perceptual) requirements of these tasks. It may be particularly important to consider the potential impact of non-executive abilities on task completion when assessing the executive function of

children, as overall performance may be affected by immaturity or delays in the development of non-executive skills, especially if the test has not been specifically developed and normed for paediatric populations (Anderson et al., 2002).

Furthermore, the multidimensional nature of executive function (described above) implies that it cannot be assessed by a single test and requires the use of multiple measures that tap into the various components of this cognitive domain. However, the literature is not always in agreement on which aspects of executive function a particular test measure; that is, the construct validity of these tests is not well established (Miyake et al., 2000). For example, while the WCST is generally described as a measure of cognitive flexibility (Heaton, 1981), some authors (Ozonoff & Strayer, 1997) have argued that it also requires high levels of inhibitory control.

In an attempt to clarify what some complex tasks of executive function really measure, Miyake et al. (2000) performed a series of structural equation modelling analyses to examine the extent to which Shifting, Updating, and Inhibition contribute to performance on more complex tasks such as the WCST and TOH. They found that Shifting is a crucial component of the number of perseverative errors on the WCST. Although the TOH is typically described as a measure of planning, Inhibition was found to contribute to performance on this test. The authors hypothesised that most people do not use a goal recursion strategy (i.e. setting up a series of sub-goals to achieve the overall goal) on these types of tasks, as it is highly demanding on working memory. Instead, they make use of a perceptual strategy, where they simply "make a move that will bring the current state perceptually closer to the goal state" (Miyake et al., 2000, p. 76). Inhibition plays an important part in this type of strategy as it requires the examinee to overcome "conflict moves" where they have to move a disk in the opposite spatial direction from its ultimate

goal, or block a goal peg temporarily, rather than make perceptually congruent moves, in order to solve the problem successfully (Miyake et al., 2000). However, subsequent studies examining the contribution of Miyake's three factors to complex executive function tasks have found inconsistent results (e.g., Lehto et al., 2003; Wu et al., 2011), and further research is therefore required to better understand the underlying cognitive demands of commonly employed measures of executive function.

Informant Ratings of Executive Function in Daily Life

Observations that there is often a discrepancy between performance on neuropsychological tests of executive function and behaviour in daily life in individuals with developmental and acquired disorders have led several authors to argue that neuropsychological tests alone are inadequate for assessing this complex domain (Anderson, 2002; Anderson et al., 2002; Gioia et al., 2008). When neuropsychological tests are developed, the focus is usually on construct validity, while little attention is paid to ecological validity (Gioia et al., 2008). However, these tests are often poor predictors of functioning in daily life (Gioia et al., 2008). This is because these measures have limited *veridicality* (i.e. they cannot accurately predict real-world outcomes such as performance at school or work) and *verisimilitude* (i.e. the demands of the tests and the conditions in which they are administered are not necessarily similar to the tasks performed in the individual's daily life) (Gioia et al., 2008; Sadek & van Gorp, 2010). Although this comment probably applies to tests designed to assess other aspects of cognition as well (e.g. memory, visuo-perceptual abilities), low ecological validity is especially problematic in the case of tests of executive function, as these abilities, by definition, manifest themselves in situations that are unpredictable, unstructured, and require novel, as opposed to routine, responses.

To address these shortcomings, various behavioural measures of executive function have been developed to specifically capture executive function as it manifests in day-to-day life. Once such measure is the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). The BRIEF consists of eight clinical scales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials and Monitor). These scales are used to compile two broader indices: the Behavior Regulation Index (BRI) and the Metacognition Index (MI), and an overall score, the Global Executive Composite (GEC). The BRIEF is normed for children aged 5- to 18-years and has a Parent, Teacher and Self-report version (the latter normed for children aged 11- to 18-years) (Gioia et al., 2000), although the majority of studies have used the Parent version.

The BRIEF has been found to be efficient in detecting behavioural symptoms specific to discrete frontal lobe pathology (e.g. frontal lesion) or frontal system dysfunction (e.g. diffuse damage, including white matter pathology) in children (Anderson et al., 2002). It has been used extensively in studies examining executive function in children with various neurodevelopmental disorders, including Attention Deficit Hyperactivity Disorder (ADHD) (Toplak et al., 2009), extremely low birth weight (Burnett et al., 2018), and Autism Spectrum Disorder (Lynch et al., 2017). As discussed in more detail below, several previous studies have found significant deficits in children with FASD on all scales and indices of the BRIEF (Mohamed et al., 2019; Nguyen et al., 2014; Rai et al., 2017; Rasmussen et al., 2007; Taylor & Enns, 2019).

However, previous studies have found mixed results regarding the relationship between scores on the BRIEF scales and neuropsychological measures of executive function. For example, in their study of adolescents (aged 13- to 18-years) with ADHD, Toplak et al. (2009) found significant but modest correlations between neuropsychological measures of

inhibition, working memory, set shifting, and planning, and both parent and teacher ratings of executive function on the BRIEF. Anderson et al. (2002) examined the relationship between performance on a variety of neuropsychological measures of executive function and the BRIEF in children (age 5-18) with brain disease (Phenylketonuria, Hydrocephalus, focal frontal lesions) and typically developing controls. They found moderate correlations between self-corrected errors on a measure of cognitive flexibility and self-monitoring (the Contingency Naming Test) and the Working Memory, Monitor, Plan/Organize, and Shift scales of the BRIEF Parent. McAuley et al. (2010) examined the association between the Behavioral Regulation (BRI) and Metacognition Indices (MI) of the BRIEF Parent and a variety of cognitive measures, including measures of executive function in a diverse clinical sample of children (aged 6- to 15-years). Neither index of the BRIEF was significantly associated with children's scores on neuropsychological tests of executive function.

To date, only four studies have evaluated the relationship between the BRIEF and neuropsychological measures of executive measures in FASD (Bernes et al., 2021; Gross et al., 2015; Mohamed et al., 2019; Rai et al., 2017). Three studies used only the Parent Form (Gross et al., 2015; Mohamed et al., 2019; Rai et al., 2017), while one used the Parent, Teacher, and Self Report Forms (Bernes et al., 2021). Three studies used subtests from the Delis-Kaplan Executive Function System (D-KEFS), a battery of neuropsychological tests specifically designed to assess executive function (Bernes et al., 2021; Gross et al., 2015; Mohamed et al., 2019). Gross et al. (2015) found low, non-significant correlations between two subtests of the D-KEFS (the Number-Letter Sequencing Condition of the Trail Making Test and the Sorting Test) and the BRIEF GEC and Initiate, Shift, and Working Memory scales in a clinical sample of children (aged 6-to 16-years) with a diagnosis of FASD (n = 551). Mohamed et al. (2019) made use of a greater number of D-KEFS subtests to assess executive function in a clinic-referred sample (n = 61) of children with FASD (aged 6- to 18-

years) and compared their performance with parent ratings on the BRIEF. Similarly, they found no significant correlations between D-KEFS and BRIEF scores, except for the Letter Fluency condition of the D-KEFS Verbal Fluency Test, which was significantly correlated with both the BRIEF Inhibit and Initiate scales. Bernes et al. (2021) examined the relationship between selected BRIEF clinical scales and performance-based neuropsychological assessments purporting to measure similar constructs in a sample of children (aged 6- to 18-years) with a history of PAE (n =47), ADHD (n = 47), and typically developing controls (n = 73). Few significant relationships were found, and effect sizes ranged from weak to moderate in all three groups (PAE, ADHD, and controls). Rai et al. (2017) used a battery of neuropsychological tests, including the WCST, the Trail Making Test Parts A and B (TMT-A, TMT-B), the Controlled Oral Word Association Test, and the Connors Continuous Performance Test – Second Edition (CPT-II) to assess executive function in a sample of Aboriginal Canadian children with FASD (n = 52) and compared the results with primary caregiver ratings on the BRIEF. An increased number of perseverative errors on the WCST was associated with better scores on the BRIEF MI and Organization of Materials scale. Slower reaction times on the CPT-II were associated with better scores on the BRIEF Organization of Materials Scale.

The low correlations between neuropsychological measures of executive function and behavioural rating scales are possibly attributable to limitations in the ecological validity and generalisability of neuropsychological measures, as discussed above (Gioia et al., 2008; McAuley et al., 2010). Thus, items on behavioural rating scales may be more specific in that they tap into behaviours linked with frontal lobe dysfunction (e.g. impulsivity), while performance on neuropsychological tests of executive function is, at least in part, dependent on intact lower-order skills such as language and visuospatial skills (Anderson et al., 2002). An alternative explanation offered by Anderson et al. (2002) is that behavioural measures and

neuropsychological tests measure different aspects of the same construct. It may be that neuropsychological tests are better equipped to tap into the cognitive aspects of executive function, typically seen as being associated with the dorsolateral frontal lobes, while behaviour rating scales measure emotional and social skills typically associated with the orbitofrontal cortex (Anderson et al., 2002). Further research using samples with discrete lesions in these two brain areas is required to support this hypothesis.

Furthermore, it is important to note that behavioural assessments rely on self- or informant-reports that also have their own set of limitations. While providing a more global view of 'executive behaviour,' rating scales may lack the ability to capture deficits in specific aspects of executive function (Gioia et al., 2008; Spiegel et al., 2017). Moreover, unlike in laboratory or clinical settings, environmental demands in an individual's daily life may vary across settings and over time, depending on expectations, thereby affecting ratings on behavioural scales (Gioia et al., 2008). Finally, rater bias (e.g. a teacher disliking a child they are rating) (Gioia et al., 2008) or recall bias (e.g. if a rater does not have regular contact with the child or has not interacted with the child for some time) (Althubaiti, 2016) may influence the results obtained on behavioural measures.

In summary, behavioural rating scales, such as the BRIEF, may offer a more ecologically valid assessment of executive function in both clinical and research settings. However, similar to neuropsychological measures, they also have several limitations. The consensus in the literature is that an executive function assessment model that integrates the findings of neuropsychological tests and behaviour rating scales constitutes the best practice (Gioia et al., 2008).

Development of Executive Function

Early models of cognitive function conceptualised executive function as an adult capacity that only reached maturity during puberty (De Luca et al., 2003). However, a growing body of research has demonstrated that executive function develops throughout childhood and adolescence, and only reaches maturity in early adulthood (Anderson, 2002; De Luca & Leventer, 2008). A full review of this large body of literature is beyond the scope of this dissertation and only a summary, focusing on the more seminal studies and those that used neuropsychological measures similar to those used in the present study, is provided.

Diamond (1985) argued that improved performance on A-not-B (AB) tasks (where an infant watches as a toy is hidden in one of two identical wells, followed by a brief delay before they are allowed to reach for it) indicates the emergence of executive function. This hypothesis was based on the observation that AB tasks are very similar to the delayed response (DR) paradigm from the animal neuroscience literature and that frontally ablated monkeys made similar perseverative errors to young infants. Diamond (1985) found that the delay between hiding and retrieval necessary to produce the AB error (i.e. perseveratively reaching for the incorrect well) increased continuously between the ages of 6- to 12-months. Observations that infants from age eight months tend to look at the correct well, while reaching for the incorrect well, have led to comparisons being drawn between young children and the dissociation between knowing and doing often observed in patients with frontal lobe lesions (Diamond, 1990). Failure at the AB task is therefore seen as a manifestation of immature inhibitory control, with improved performance mediated by increasing maturity of the prefrontal cortex (Diamond, 1990). Espy et al. (1999) extended these findings by examining the performance of 117 preschool children (aged 23- to 66-months) on the AB task as well as other age-appropriate measures of working memory and problem solving.

They found significant age-related gains, with children older than five years achieving perfect AB performance on a 10-second delay. The results of their EFA suggest that successful AB performance depends on the deployment of both working memory and response inhibition.

Gerstadt et al. (1994) used a simplified version of the Stroop task (a measure of inhibitory control widely used clinically and in research on adult patients with frontal lobe lesions) to examine the development of the ability to inhibit prepotent responses in children aged 3.5- to 7-years (n = 240). They found a marked improvement in response latency between the ages of three and four years, with no improvement thereafter. All the children performed well in terms of percentage of correct trials at the outset of testing, and all children's performance deteriorated as the test progressed. However, this deterioration was much more marked in younger children (3.5- to 4.5-year-olds) than in older children (5- to 7-year-olds). Children's performance on a control condition suggested that the poor performance of the younger children could not be attributed to them failing to understand the instructions, an inability to remember the rules, or a short attention span. Therefore, the authors hypothesised that younger children may exert more effort to inhibit prepotent responses, leading to cognitive fatigue and a breakdown in performance (Gerstadt et al., 1994).

In another study with preschool children, Jacques and Zelazo (2001) used the Flexible Item Selection Task, a task adapted from the Visual-Verbal Test, and a simplified version of the WCST to examine two other aspects of executive function, namely cognitive flexibility and abstraction abilities. They assessed 2- to 5-year-olds (n = 197) but excluded the 2-year-olds from analysis as most of them failed to understand the task requirements. Relative to the two older age groups, 3-year-olds had difficulty with the abstraction component of the task. In contrast, 4-year-olds performed as well as 5-year-olds on the abstraction component of the

task, but substantially worse on the cognitive flexibility component, providing evidence for the development of this aspect of executive function during preschool years (Jacques & Zelazo, 2001).

Luciana and Nelson (1998) used the CANTAB to examine the development of working memory in a sample of typically developing children aged 4- to 8-years (n = 181), a small group of adolescents (n =7), and young adults (n = 17). There was a general trend for 4-year-olds to perform significantly worse than other age groups on all tasks administered, although the authors hypothesised that this may be related to a lack of maturity in terms of non-executive abilities, such as less efficient responses to sensory stimuli, poor sequencing, and recognition memory. While 5- to 7-year-olds could perform these basic tasks at an equivalent level to older children and adults, they were only able to perform working memory tasks with relative ease when the demands were low and displayed an increase in the number of errors and a decrease in the use of strategy when the task demands were higher. The authors argue that this suggests the emergence of executive function, and hypothesise that lack of maturity in the neural circuity linking the prefrontal cortex with other structures leads to a breakdown in executive abilities when the prefrontal cortex has to perform multiple functions simultaneously (Luciana & Nelson, 1998). While 8-year-olds obtained similar strategy scores on the Spatial Working Memory (SWM) task as young adults, they demonstrated an elevated number of forgetting errors. The authors hypothesised that this pattern of performance suggests that 8-year-old children make use of executive processes to guide strategy formulation, but fail to implement these strategies because the information is not adequately integrated between the prefrontal cortex and other brain structures that subserve sequencing, spatial processing, and/or recognition memory (Luciana & Nelson, 1998).

De Luca et al. (2003), extended these findings into adolescence and adulthood when they made use of four subtests of the CANTAB; Spatial Span, SWM, TOL, and Intradimensional/Extradimensional Set-Shifting (ID/ED), to examine the development of executive function across the lifespan in a sample of 8- to 64-year-olds (n = 194). They divided their sample into six age groups: 8- to 10-year-olds (n = 29), 11- to 14-year-olds (n = 29), 15- to 19-year-olds (n = 39), 20- to 29-year-olds (n = 39), 30- to 49-year-olds (n = 39), and 50- to 64-year-olds (n = 19). They found functional gains in the efficiency of working memory, planning, and problem-solving between the ages of 15- to 19-years and again between the ages of 20- to 29-years. In contrast, even the youngest age group performed at adult levels on a measure of cognitive flexibility.

Similar results were found by Levin et al. (1991) who assessed 52 children and adolescents on measures of executive function and memory. Participants were divided into three age groups: 7- to 8-year-olds (n = 17), 9- to 12-year-olds (n = 17) and 13- to 15-year-olds (n = 18). The authors found major gains between the 7- to 8-year-old group and the 9- to 12-year-old group on two tasks in particular: the WCST (a measure of problem solving and concept formation) and a Go/No-go task (a measure of inhibitory control). Greater output efficiency as a function of increasing age was also seen on measures of both verbal and nonverbal fluency across all three groups. Adolescents displayed further advances in performance on the Twenty Question and TOL tasks, both measures of problem solving and concept formation (Levin et al., 1991).

Using a large sample (n = 400) of healthy children, Klenberg et al. (2001) demonstrated improvements in attentional control, goal setting, and cognitive flexibility between the ages of 7 and 12 years using subtests of the NEPSY. Motor inhibition and impulse control were among the first aspects of executive function to reach the 12-year-old

level (indicating maturity) at age 6. Performance on a goal-setting task (the Tower subtest) reached maturity by age eight, while relative maturity on tests of focused and sustained attention was reached by the age of ten. Verbal and non-verbal fluency was the last to mature, with no evidence of levelling off, even in the oldest age groups. The authors hypothesised that fluency tasks are complex executive tasks that require active use of strategy, monitoring, and evaluation of ongoing performance (Klenberg et al., 2001).

In one of the few studies focusing specifically on the development of executive function in late childhood and adolescence, Anderson, Anderson, et al. (2001) assessed 138 children (aged 11.0- to 17.11-years) using measures of attentional control, cognitive flexibility, and goal setting. Participants were divided into six groups (11.0- to 11.11-year-olds, 12.0– to 12.11-year-olds, 14.0– to 14.11-year-olds, 15.0– to 15.11-year-olds, and 16.0– to 17.11-year-olds). The authors found a relatively flat developmental trajectory during this period, compared to the rapid maturation observed during early and middle childhood, although there was evidence of a developmental spurt in attentional capacity and cognitive flexibility at around age 15 years. In addition, their results suggest a subtle increase in planning skills throughout adolescence (Anderson, Anderson, et al., 2001).

Luna et al. (2004) made use of a series of oculomotor tasks to investigate the development of processing speed, voluntary response suppression, and spatial working memory in sample of 8- to 30-year-olds (n = 245). They found that response inhibition reached adult levels by the age of 14, processing speed by the age of 15, and working memory by the age of 19. While the development of processing speed was not affected by the development of the other two domains, both processing speed and response inhibition had a modest influence on the development of working memory. The authors hypothesised that faster processing of information may allow information to be encoded more efficiently in

working memory, whereas better response inhibition would allow for the suppression of irrelevant information, thereby decreasing the demands on working memory (Luna et al., 2004).

In summary, the literature suggests that executive function begins to emerge from the age of 12 months and develops throughout childhood. In addition, research indicates that components of executive function may demonstrate different developmental trajectories, with attentional control emerging in infancy and being relatively well developed by the age of nine years, while other aspects of executive function, such as cognitive flexibility, goal setting, and information processing, only achieve relative maturity by age 12 years (P. Anderson, 2002). Executive function continues to improve during adolescence and early adulthood, reflecting the better implementation and integration of these skills with increasing age (Anderson, 2008; V. Anderson et al., 2008; Anderson, Anderson, et al., 2001).

These differential rates of maturation complicate our understanding of executive function in children tremendously, and imply that executive dysfunction may manifest differently depending on the child's developmental age (Anderson, 2002). As will be discussed in more detail below, most studies investigating executive deficits in children with FASD have used very large age ranges and have often not made age-related comparisons. The practice of grouping children of different ages, and therefore different developmental stages, together may obscure important differences in the developmental trajectory of children with FASD and typically developing children. This may partially explain why studies examining the same domains of executive function have found discrepant results.

Biological underpinnings of executive function

In adults, executive function has traditionally been ascribed to the prefrontal cortex (Mesulam, 2013; Stuss & Benson, 1986). However, the prefrontal cortex is linked to almost all cortical structures through efferent and afferent connections (Stuss & Benson, 1986), and it is now generally accepted that intact executive function requires the integrity of the entire brain (V. Anderson et al., 2008). Therefore, both discrete frontal lobe pathology and white matter damage or lesions to other areas of the brain may lead to executive deficits (Alexander & Stuss, 2000; Eslinger & Grattan, 1993).

Although the anatomical areas underpinning executive function in children may be similar to those of adults, important differences exist with respect to their maturity (V. Anderson et al., 2008). The brain develops rapidly in the first year of life, with grey matter volume increasing more rapidly than white matter (Gilmore et al., 2018). Histological and imaging studies suggest that prefrontal areas and the white matter tracts that connect them with other areas of the brain undergo a protracted period of development during childhood (Giedd et al., 1999; Reiss et al., 1996; Toga et al., 2006). This appears to coincide with the parallel development of executive skills (V. Anderson et al., 2008) as described above. Adolescence is characterised by more subtle brain development, with MRI studies showing a global decrease in grey matter volume and concomitant increases in white matter (Giedd et al., 1999; Reiss et al., 1996). Diffusion tensor imaging (DTI) studies have demonstrated continuous maturation of white matter from childhood to adulthood (Asato et al., 2010; Bava et al., 2010). While broadly distributed association and projection fibres appear to mature by adolescence, prefrontal-striatal connections, which support executive function, have been found to mature only after adolescence (Asato et al., 2010). The development of cortico-cortical connections during late adolescence is likely to support young adults in implementing

executive function skills in a more comprehensive, abstract, and flexible manner (De Luca et al., 2003).

FASD and Performance on Neuropsychological Measures of Executive Function

While the presence of executive dysfunction in children with a history of PAE is well documented, it is not clear whether all domains of executive function are equally affected, in other words, whether there is an 'executive profile' that is characteristic of FASD. Various studies have attempted to elucidate such a profile, or at least identify a common aspect of executive function that is impaired in children with FASD; however, such studies have often obtained variable results.

In one of the earliest studies focusing specifically on executive deficits in children with FASD, Kodituwakku et al. (1995) compared the performance of children (aged 9- to 18-years) with FASD (n = 10) with that of control participants (n = 10) on measures of planning, behavioural regulation (i.e. inhibition), and utilisation of feedback (i.e. cognitive flexibility). Children with FASD displayed significant deficits relative to controls on measures of planning (e.g. Progressive Planning Test) and tasks that required the utilisation of feedback/cognitive flexibility (e.g. WCST). More variable results were found for measures of behavioural regulation, with the FASD group exhibiting no difficulties relative to controls on the Delayed-Response Task or Subject-Ordered Task, both of which require continuous upgrading of working memory and the inhibition of salient responses. In terms of verbal fluency, the FASD group performed worse on a letter fluency task, but not on a category fluency task, than the controls. Based on the high correlations between the tasks that distinguished the two groups, the authors hypothesised that a common mechanism, namely the ability to flexibly manage goals in working memory, is impaired in children with FASD (Kodituwakku et al., 1995).

Subsequent studies have confirmed that deficits in working memory are common in both children (Green et al., 2009; Jacobson, 1998; Moore et al., 2021) and adults (Kerns et al., 1997) with a history of PAE. However, in keeping with theoretical models of executive function (discussed above), other aspects of executive function have been found to impact the working memory performance of individuals with PAE. For example, in a study examining the relationship between processing speed and prenatal alcohol exposure, Burden et al. (2005) assessed response speed and cognitive efficiency in a sample of 337 children (aged 7.5- to 7.9-years) with a confirmed history of moderate to heavy alcohol exposure. Prenatal alcohol exposure was found to be associated with both slower processing speed and reduced working memory. Their data also suggests that deficits in working memory are partially accounted for by the impact of PAE on processing speed (Burden et al., 2005).

Studies examining executive function in children with FASD have used a variety of neuropsychological tools that make different demands on baseline (i.e. non-executive abilities), thereby making it difficult to directly compare and qualitatively summarise results (Kingdon et al., 2016). However, even when studies used the same measures, they often found discrepant results. For example, Mattson et al. (1999) used four subtests (the Tower Test, Colour-Word Interference Test, Word Context Test, and Trail Making Test) from the D-KEFS to evaluate the executive function of children with PAE. Their sample consisted of 18 children (aged 8- to 15-years) with a history of heavy alcohol exposure with (n = 10) and without (n = 8) a diagnosis of FAS, and control participants (n = 10). The alcohol-exposed group exhibited impairments relative to controls in all four domains of executive functioning assessed: planning, inhibition, abstract thinking, and cognitive flexibility (Mattson et al., 1999). Using the Design Fluency and Verbal Fluency subtests from the D-KEFS, Schonfeld et al. (2001) assessed verbal and non-verbal fluency in a small sample of children (aged 8- to 15-years) with heavy prenatal alcohol exposure, but no diagnosis (n = 8) and children

diagnosed with FAS (n = 10) compared to typically developing controls (n = 10). Children with a history of PAE exhibited deficits in both verbal and nonverbal fluency relative to controls. On the verbal fluency tasks, letter fluency and category fluency were equally impaired (Schonfeld et al., 2001). In contrast, Kodituwakku et al. (2006) found that although children (aged 6- to 9-years) with FAS (n = 62) displayed deficits compared to control participants (n = 61) in both letter and category fluency, they had greater difficulty with the letter fluency task. Rasmussen and Bisanz (2009) assessed children (aged 8- to 16-years) with FASD (n = 29) on eight subtests of the D-KEFS to obtain a profile of the different domains of executive function in this population. Relative to normative data, children with FASD presented with significant deficits on tasks that required hypothesis testing, categorisation, concept formation, and cognitive flexibility (e.g., 20 Questions Test, Card Sorting Test). In keeping with the findings of Mattson et al. (1999), these children also had significant difficulty on measures of cognitive flexibility and inhibition (Rasmussen & Bisanz, 2009). However, unlike Mattson et al. (1999), no significant difficulties were found on the D-KEFS Tower test, a measure of planning and use of strategy. Schonfeld et al.'s (2001) finding of reduced nonverbal fluency was also not replicated (Rasmussen & Bisanz, 2009). In verbal fluency tests, children with FASD had significant difficulties in letter fluency and category switching tasks but performed relatively well on the category fluency task (Rasmussen & Bisanz, 2009).

Differences in methodological approaches might explain these discrepant findings, as both Mattson et al. (1999) and Schonfeld et al. (2001) compared FASD and control groups using raw data, while Rasmussen and Bisanz (2009) made use of scaled scores, which are normed by age. In addition, several of these studies had small sample sizes, which limits the generalisability of the findings. The literature also suggests that several factors may moderate

the relationship between FASD and executive difficulties. These factors are discussed in more detail later in this chapter.

In a meta-analytic study, Khoury et al. (2015) reviewed 46 studies that compared children with FASD with control participants using a variety of executive function measures. The authors used the three-factor model of executive function proposed by Miyake et al. (2000) to review the available evidence for impairments in working memory, inhibition, and set-shifting associated with PAE. A medium effect size was found when they compared the FASD and control groups across all executive function domains. Separate analysis of their three executive domains suggested divergence in terms of the magnitude of the effects, with medium effects present for working memory and inhibition and large effects for set-shifting (Khoury et al., 2015). In another meta-analytic study, Kingdon et al. (2016) reviewed 51 studies comparing executive function of children with FASD with ADHD or typically developing control groups. Six executive function domains were included: (i) fluency, (ii) inhibition, (iii) planning, (iv) set-shifting, (v) vigilance, and (vi) working memory. The overall effect size revealed moderate executive deficits for FASD groups compared to typically developing children. Effect sizes were then grouped according to executive function domains to examine the profile of executive strengths and weaknesses. Large deficits in planning, fluency, set-shifting, and working memory, and moderate deficits in vigilance and inhibition were found (Kingdon et al., 2016).

FASD and Deficits on Behaviour Rating Scales of Executive Function

Children with FASD have well-described behavioural difficulties, including problems with hyperactive and aggressive behaviour (Tsang et al., 2016), poor social skills (Rasmussen et al., 2011), and deficits in adaptive functioning (Crocker et al., 2009; Ware et al., 2014; Whaley et al., 2001). In the developmental neuropsychological literature, children with focal

frontal lobe lesions and associated executive dysfunction are often described as impulsive and argumentative, lacking motivation and drive, showing a disregard for social rules, failing to learn from mistakes, and being inflexible in their thinking (Anderson, 2002).The similarities between the behaviour of children with focal frontal lobe lesions and children with FASD have led several authors to hypothesise that deficits in executive function may, to some extent, account for the behavioural and social problems commonly observed in individuals with FASD (Crocker et al., 2009; Kodituwakku, May, et al., 2001; Ware et al., 2012). This hypothesis is supported by findings that poor executive functioning is related to impaired social problem-solving (McGee et al., 2008; Schonfeld et al., 2006) and deficits in adaptive functioning (Ware et al., 2012) in children with FASD.

However, executive function has primarily been studied through the administration of standardised neuropsychological tests. As discussed above, neuropsychological measures of executive function may not reflect how individuals function in their everyday lives; in other words, these measures have poor ecological validity. Several studies of children with FASD have therefore made use of behaviour-rating scales to measure the integrity of executive function in the "real world." The most common measure utilised is the BRIEF (Gioia et al., 2000), which is described in detail earlier in this chapter.

Most studies conducted to date have compared mean *t*-scores for children with FASD with the BRIEF standardisation sample. These studies have consistently demonstrated mean scores in the clinically impaired range (defined as *t*-scores above 65) on the GEC (Astley, Olson, et al., 2009; Gross et al., 2015; McGee et al., 2008; Mohamed et al., 2019; Nash et al., 2015; Rai et al., 2017; Rasmussen et al., 2007; Stevens et al., 2013; Wozniak et al., 2013), the BRI (Astley, Olson, et al., 2009; McGee et al., 2008; Mohamed et al., 2019; Nash et al., 2015; Rai et al., 2017; Rasmussen et al., 2007; Stevens et al., 2013) and the MI (Astley,

Olson, et al., 2009; Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2007; Stevens et al., 2013) in FASD samples. Studies that compared children with FASD with a study-specific sample of typically developing children have similarly found that parents rate children with FASD as exhibiting significantly more executive difficulties in their everyday lives on the GEC, BRI, and MI (Knuiman et al., 2015; McGee et al., 2008; Wozniak et al., 2013).

Studies using the BRIEF have mainly used the Parent Form. To date, only three studies have used the Teacher Form (Rasmussen et al., 2006; Stevens et al., 2013; Taylor & Enns, 2019). This is problematic since studies comparing parent and teacher ratings of children with FASD in other areas of functioning have generally found a higher incidence of behavioural problems in the school compared to the home environment (Tsang et al., 2016). It is unclear whether the same applies to ratings of executive function, as studies employing the BRIEF Teacher Form have found contradictory results. Stevens et al. (2013) compared the behavioural function of 109 children (age 6- to 16-years) with a diagnosis of FASD with that of 61 children with a history of prenatal alcohol exposure but who did not meet criteria for a FASD diagnosis on a variety of behavioural measures including the BRIEF. They found significant differences between children who were diagnosed with FASD and those who did not receive a diagnosis on the Parent Form, but not the Teacher Form of the BRIEF. The authors hypothesised that the structure of the classroom might support the executive function of children with FASD in the educational environment (Stevens et al., 2013). However, in their study using a sample of 50 clinic-referred children (aged 6- to 16-years) diagnosed with FASD, Rasmussen et al. (2006) found that teacher ratings were significantly higher than parent ratings on the GEC of the BRIEF. Taylor and Enns (2019) conducted retrospective chart review of 315 children and adolescents (aged 5- to 18-years) who presented for assessment at a FASD Centre in Canada with a history of confirmed PAE. Parent and teacher ratings on the BRIEF and other behavioural measures were compared for those who had

received a FASD diagnosis (n = 161) and those who had not (n = 154). Direct logistic regressions analysed the contributions of different ratings on the likelihood of an FASD diagnosis. The BRIEF Parent Shift, Emotional Control, and Initiate Scales, as well as the BRIEF Teacher Metacognitive Index variables, were selected for the logistic regression based on significant association to an FASD diagnosis and multicollinearity. The final regression model was statistically significant. While all three of the parent-rated scales were non-significant, only the teacher-rated MI tended towards significance. The authors hypothesised that teachers may be more experienced in observing and accurately rating behaviour because of their training and daily exposure to a wide range of typically developing children. Additionally, the classroom environment may place different demands on children (Taylor & Enns, 2019).

FASD and Executive Function: Moderating Factors

Several factors may moderate the relationship between FASD and executive difficulties. This includes the type of FASD diagnosis, intellectual ability, socio-economic factors, and other risk factors, such as premature birth, low birth weight, and comorbid health conditions. These factors are discussed in more detail below.

Diagnosis, Dose, Duration and Gestational Timing of Prenatal Alcohol Exposure

Research suggests that the severity of neurodevelopmental outcomes resulting from PAE is related to the dose, duration, and gestational timing of exposure (Flak et al., 2014; Hasken et al., 2021; Jacobson et al., 2024; May et al., 2023). A recent study by May et al. (2023) analysed consolidated data from seven population-based studies employing active case ascertainment across five communities in South Africa's Western Cape province. Women whose children were diagnosed with FAS consumed notably higher quantities of

alcoholic beverages per occasion and per week, demonstrated the greatest incidence of binge drinking, and were more likely to have consumed alcohol prior to and throughout all three trimesters of pregnancy. The mothers of children diagnosed with PFAS and ARND exhibited a different pattern of alcohol consumption than mothers of children diagnosed with FAS and mothers of typically developing children. Mothers across all FASD groups reported their most intense and frequent alcohol consumption before becoming pregnant and during the initial three months of pregnancy. During the second and third trimesters, a greater proportion of mothers in the PFAS and ARND groups ceased alcohol consumption compared to those in the FAS group; nonetheless, the women who persisted in drinking maintained similar levels and regularity of alcohol intake as they had prior to pregnancy and during the first trimester. Mothers of children diagnosed with ARND and PFAS were less likely to engage in binge drinking compared to those whose children were diagnosed with FAS, particularly when considering episodes involving more than five alcoholic beverages per occasion (May et al., 2023).

While the adverse impact of heavy PAE and/or frequent binge drinking on neurodevelopment is well documented, the relationship between low-to-moderate PAE and neurodevelopmental outcomes is less well understood. Some studies have documented mostly no effect, while others have even suggested a potential protective association between low-to-moderate PAE and neurodevelopmental outcomes (see Bandoli et al., 2023 for review). In their meta-analysis, Flak et al. (2014) found no significant association between mild-to-moderate PAE (>0–6 drinks per week) and a broad range of neuropsychological outcomes (cognition, behaviour, visual and motor development, academic development, attention, language, memory, and executive function). However, they found an association between moderate prenatal alcohol exposure and child behaviour. Pyman et al. (2021) conducted a systematic review and meta-analysis of 13 studies to examine the relationship

between dose of exposure and various domains of attention (encode, focus, shift, sustain, and behavioural) in children. They identified a notable detrimental impact of any PAE on the ability to shift attention as well as a potential negative effect of heavy PAE on encoding. Compared to control groups, the data suggest that low-to-moderate PAE is linked to an increased likelihood of attention-related behavioural difficulties (Pyman et al., 2021). Bandoli et al. (2023) identified a range of methodological issues (including a lack of consensus on how low to moderate levels of PAE are defined across studies) and moderating factors (such as SES) which may account for inconsistencies in findings.

Few studies have specifically compared different FASD diagnostic groups on measures of executive function, and those that have often found inconsistent results. For example, Mattson et al. (1999) compared the performance of a sample of children who met the criteria for FAS (n = 10) with that of children who had a history of heavy alcohol exposure but lacked the pattern of facial features and growth deficiency (n = 8). They found no differences in any of the executive function tests administered, except for performance on the Switching condition of the Colour-Word Interference Test (Mattson et al., 1999). Similarly, Schonfeld et al. (2001) found no significant differences between alcohol-exposed children with and without the facial features of FAS on measures of verbal and non-verbal fluency. Green et al. (2009) used four tasks from the CANTAB to assess attention, planning, strategy use, and spatial working memory in children with FAS (n = 24), pFAS (n = 18), and ARND (n= 40). A sample of control participants (n = 92) was matched with the children for each of the three diagnostic subgroups based on age and sex. All three FASD groups performed significantly worse relative to controls. There were no significant differences between the diagnostic subgroups for any of the measures used, except for the Stockings of Cambridge, a measure of planning and strategy use. On this measure, children with a diagnosis of FAS solved significantly fewer problems than children with a diagnosis of pFAS

or ARND (Green et al., 2009). Chasnoff et al. (2010) compared the performance of a sample of 72 foster and adopted children (aged 6- to 11-years) with diagnoses of FAS, pFAS or ARND on a range of measures. Children with FAS performed significantly worse on a sequencing and shifting task, the Children's Color Trials Test. No significant differences were found between the three groups on the BRIEF Parent rating scale or WCST (Chasnoff et al., 2010).

In their meta-analysis, Kingdon et al. (2016) found that the overall effect size showed moderate deficits for alcohol-exposed children without the characteristic facial features, relative to controls. The effect size estimate for the non-dysmorphic FASD groups relative to controls did not differ significantly from that obtained for the dysmorphic FASD groups relative to controls. Similarly, .Khoury et al. (2015) noted that working memory, inhibition and set-shifting effect sizes did not differ based on FASD diagnostic classification.

Executive function appears to be adversely affected in children with a history of heavy alcohol exposure, even in cases where characteristic facial features are absent (Green et al., 2009; Mattson et al., 1999; Schonfeld et al., 2001). Animal studies have indicated that cells in the CNS have a lower threshold for alcohol injury and may therefore experience more rapid cell death than other cells in the embryo (Dunty et al., 2001). This may explain why some individuals with a history of PAE present with significant cognitive and behavioural dysfunction, despite the absence of facial features (Welch-Carre, 2005). In addition, it is important to note that PAE only produces the characteristic facial features of FAS during a highly specific period in gestation, around the first trimester (Rasmussen, 2005). Therefore, the facial features of FAS may not be an accurate indicator of the severity of CNS damage caused by PAE at all gestational stages (Connor et al., 2000).

General Intelligence

Reduced general intelligence is one of the most common neurocognitive findings associated with prenatal alcohol exposure (Mattson et al., 2019; Mattson et al., 2011). Some individuals with significant executive deficits due to focal frontal lobe lesions have been found to obtain scores in the average range on standard tests of intelligence (Friedman et al., 2006). This suggests that executive function may be unrelated to general intelligence, possibly because intelligence tests mainly tap crystallised intelligence (i.e. acquired knowledge) rather than fluid intelligence (i.e. reasoning and problem-solving abilities) (Anderson, 2008).

Research examining executive function deficits in children with FASD has yielded inconsistent results. Some investigations have found no correlation between IQ and performance on executive function assessments (Kodituwakku et al., 2006; Rasmussen et al., 2013). In contrast, other studies have indicated that certain aspects of executive function impairments observed in individuals with FASD may be attributed to lower IQ scores (Connor et al., 2000). In their meta-analysis, Khoury et al. (2015) found that IQ was a significant moderator of inhibition and working memory outcomes but not of set-shifting. Similarly, Kingdon et al. (2016) reported larger effect sizes, indicating more severe executive function difficulties, in FASD groups compared to healthy controls for studies where there were greater IQ differences between groups.

Age

The presence of executive dysfunction in individuals with a history of PAE has been documented in preschoolers (Fuglestad et al., 2015; Noland et al., 2003), school-aged children and adolescents (Burden et al., 2009; Burden et al., 2005; Coles et al., 1997; Green

et al., 2009; Kodituwakku et al., 2006; Kodituwakku et al., 1995; Mattson et al., 1999; Schonfeld et al., 2001), and adults (Connor et al., 2000; Kerns et al., 1997; Mela et al., 2020; Rangmar et al., 2015). However, many studies in the field have used large age ranges (usually 8- to 18-years) and have often not made age-related comparisons. This is problematic since, as discussed above, executive function develops with increasing age. In a developmental context, a poor performance on tests of executive function may therefore not constitute a permanent 'deficit' (Anderson, 2002), but may possibly reflect a delay in which there may be catch-up at a later developmental stage.

In one of the few studies examining age-related differences in performance on tests of executive function, Kodituwakku et al. (2006) hypothesised that children with FAS aged 6- to 9-years (n = 62) would show age-related changes in performance on tests of category fluency, but not letter fluency. They based this hypothesis on findings from developmental studies that suggest that the skills involved in letter fluency develop more slowly than those involved in category fluency (Riva et al., 2000). However, this hypothesis was not supported, as children with FAS were found to exhibit age-related gains in performance on both category and letter fluency tasks. The authors interpreted this finding as evidence of brain plasticity in children with FAS (Kodituwakku et al., 2006). In a cross-sectional study, Badenhorst (2007) found that 6- to 7-year-olds (n = 10), but not 12- to 13-years-olds (n = 10) with confirmed PAE, performed poorly compared to typically developing control participants on measures of focused and sustained auditory attention, visual attention, inhibition, and planning of the NEPSY. This suggests that PAE may lead to developmental delays which manifest as deficits in younger children and that these deficits may dissipate as children grow older and 'catch up' with their peers. However, Rasmussen and Bisanz (2009) found contradictory results. They examined the performance of 29 children with FASD (aged 8- to 16-years) on eight subtests of the D-KEFS. Relative to the normative data for this test, older children performed

worse than younger children on measures of verbal fluency, inhibition, cognitive flexibility, and abstract reasoning. The authors concluded that some executive function skills may develop slower than others in children with FASD. Tamana et al. (2014) used the Trail Making Test A and B to compare the performance of two age groups (9– to 12-year-olds and 13– to 17-year-olds) diagnosed with FASD. Older children displayed significantly greater difficulty (relative to published norms) than did younger children. Taylor and Enns (2018) compared a large sample (n = 238) school-aged children (age 6- to 12-years) and adolescents (age 12- to 18-years) with a confirmed history of PAE on a range of cognitive measures, including tests of executive function. They divided the sample into children and adolescents diagnosed with FASD and a nondiagnosed group. Performance on executive function tests contributed to the ability to differentiate between diagnosed and non-diagnosed children (Taylor & Enns, 2018).

In their meta-analytic study, Khoury et al. (2015) found that differences in mean age between FASD and comparison groups significantly predicted effect sizes for FASD-related deficits in working memory and set shifting, and approached significance for inhibition. Similarly, Kingdon et al. (2016) found that studies with older mean age samples had larger effect sizes, indicating more pronounced executive difficulties in FASD groups than in typically developing children with increasing age.

There is some evidence that older children with FASD may also display more executive difficulties in their daily lives (as measured by behavioural rating scales) than younger children. Rasmussen et al. (2007) found that older children (aged 9- to 16-years) had significantly worse scores (relative to the normative data) on the Initiate and Working Memory scales of the BRIEF Parent compared to younger children (aged 5- to 8-years). The authors hypothesised that adolescence may place additional demands on executive function

which could result in more pronounced deficits in these areas. However, they also acknowledged that other factors, such as older children being more affected by alcohol, being diagnosed later in life, or having received less intervention or support, may have also contributed to this finding (Rasmussen et al., 2007).

Socioeconomic Status

Socioeconomic status (SES) refers to a combination of material wealth (e.g. family income) and non-economic characteristics (e.g. education) and is associated with differences in physical health, mental health, and cognitive ability (Hackman & Farah, 2009). The relationship between SES and cognitive development is complex and multifactorial, and a full discussion is beyond the scope of this dissertation. Therefore, only a brief summary will therefore be provided here.

SES is known to have a strong relationship with performance on cognitive tests including IQ (Noble et al., 2005). Thus, for example, several South African studies have found that individuals from low SES backgrounds perform significantly below international normative data on IQ tests, such as the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV) and the Wechsler Adult Intelligence Scale, 4th edition (WAIS-IV) (Pienaar et al., 2016; Shuttleworth-Edwards et al., 2004).

Several studies have shown that childhood SES impacts on the development of executive function specifically (Ardila et al., 2005; Cave & Grieve, 2009; Evans & Schamberg, 2009; Lipina et al., 2013; Lipina et al., 2005; Mezzacappa, 2004; Stevens et al., 2009). For example, Lipina et al. (2005) found that infants from lower-SES families made fewer consecutive correct responses and made more perseverative and non-perseverative errors than non-poor infants on the AB task, an early predictor of executive function. Four-

year-old children from lower SES backgrounds have been found to perform significantly worse on non-verbal tests of executive functioning, including measures of attentional control, working memory, and planning (Lipina et al., 2013). Similarly, Mezzacappa (2004) found that socially advantaged 4– to 7-year-old children were significantly better than their disadvantaged counterparts at resisting the interference of competing demands on a measure of executive attention. Stevens et al. (2009) demonstrated that 3-to 8-year-old children whose mothers had a lower level of educational attainment (no college experience) have significantly more difficulty filtering out irrelevant information compared to children whose mothers had a higher level of education (at least some college). Evans and Schamberg (2009) found that the duration of poverty throughout childhood development was inversely related to working memory in young adults. Children from disadvantaged socioeconomic backgrounds not only exhibit poor performance on neuropsychological assessments of executive function but also demonstrate increased executive challenges in their everyday activities. Cuartas et al. (2022) demonstrated socioeconomic status-related disparities in dysregulation among preschool-aged children, as evidenced by parent and educator ratings on the BRIEF. Similarly, Halse et al. (2019) observed that higher parental education is associated with enhanced everyday executive function in children aged 6 to 10 years.

Several studies have flagged differences in quality of education received by advantaged versus disadvantaged children as a significant mediating factor in the development of executive function. For example, Ardila et al. (2005) found robust differences in performance on a range of executive function measures between children attending private schools and children attending public schools in Colombia and Mexico. Similarly, in a South African study specifically investigating the relationship between quality of education and performance on neuropsychological tests, Cave and Grieve (2009) found that Grade 11 and Grade 12 children attending under resourced schools performed

significantly worse on several measures of executive function than children attending well-resourced schools.

Socioeconomic factors, therefore, appear to have a profound impact on cognitive development in general and executive function in particular. Although FASD is known to occur across all SES levels, children with FASD are more likely to be born to mothers from lower SES communities (Abel, 1995; May et al., 2005; May, Tabachnick, et al., 2013), and children from lower SES backgrounds are likely to have experienced higher levels of alcohol exposure, leading to more severe neurodevelopmental difficulties (Connor et al., 2020). While some studies investigating executive function in FASD controlled for SES, or at least conducted an analysis to investigate the relationship between performance on measures of executive function and SES (e.g., Mattson et al., 1999; Schonfeld et al., 2001), or selected FASD and control samples from the same SES and ethnic groups (Coles et al., 1997), this has not consistently been the case, highlighting the need for further research in this area.

Other risk factors

Children with FASD, especially those exposed to frequent binge drinking during pregnancy, are at increased risk for adverse outcomes, including preterm birth (Bakhireva et al., 2024; Coles et al., 2019; Hasken et al., 2021), low birth weight or being small for gestational age (Bakhireva et al., 2024; Hasken et al., 2021), and a range of birth defects, including cardiac defects, oral clefts, and herniation defects (Dyląg et al., 2023). These adverse outcomes may, in and of themselves, be risk factors for executive difficulties.

For example, children born preterm (defined as birth before 37 weeks of gestation) or with low birth weight (defined as < 2500 g) have been shown to exhibit impairments in both performance-based and behavioural measures of executive function (Burnett et al., 2015;

Taylor et al., 2004). While children born extremely preterm (<28 weeks gestation) and/or extremely low birth weight (<1000 g) may be particularly at risk for executive difficulties, late preterm children (born between 34-36 weeks gestation) may also present with delayed development of executive function skills, especially in the early childhood period (Martínez-Nadal & Bosch, 2020). Similarly, some birth defects such as cardiac defects have been associated with neurodevelopmental difficulties. For example, a recent meta-analysis by (Feldmann et al., 2021) found that children with congenital heart disease performed worse than control participants on measures of executive function.

Children with FASD are also at increased risk for a range of comorbid conditions, including attention-deficit/hyperactivity disorder (ADHD), Conduct Disorder, Oppositional-Defiant Disorder, anxiety, and mood disorders (Connor et al., 2020). Some of these conditions, particularly ADHD, are also associated with executive deficits (Glass et al., 2013; Khoury & Milligan, 2019; Rasmussen et al., 2010; Toplak et al., 2009). This underscores the necessity of considering differential diagnoses as part of the FASD assessment.

Neural Correlates of PAE and its Relation to Executive Dysfunction

Numerous studies have shown that PAE leads to a wide array of structural changes in the brain, including a reduction in overall brain size, reduced cerebellar volume, agenesis of the corpus collosum, and small hippocampi (Autti-Ramo et al., 2002; Clark et al., 2000; Donald et al., 2015; Sowell et al., 1996; Swayze et al., 1997). Longitudinal studies have found that individuals with PAE have altered developmental trajectories in cortical volume changes compared to typically developing controls, suggesting that brain development continues to be adversely affected long after prenatal insult due to alcohol exposure (Hendrickson et al., 2018; Lebel et al., 2012).

The neural correlates of executive dysfunction in FASD are still poorly understood since limited evidence exists for structural changes to the prefrontal cortex specifically, the area of the brain most often implicated in executive function (Kodituwakku, Kalberg, et al., 2001). Using MRI, Sowell et al. (2002) found significant decreased brain surface in the ventral aspects of the frontal lobes, particularly in the left hemisphere. Astley, Aylward, et al. (2009) observed significantly smaller absolute volumes of white and grey matter in the frontal lobes of subjects with FASD than in non-alcohol-exposed controls. Functional MRI studies have found abnormal frontal lobe activation in individuals with FASD during both spatial (Malisza et al., 2005) and verbal (O'Hare et al., 2009) working memory tasks.

In recent years, it has become clear that white matter is particularly vulnerable to prenatal alcohol exposure (Sowell et al., 2008). The presence of reduced white matter volume (Archibald et al., 2001; Lebel et al., 2008) and abnormalities in the corpus callosum (Autti-Ramo et al., 2002; Clark et al., 2000; Riikonen et al., 1999; Riley et al., 1995; Swayze et al., 1997) following PAE is well established. Findings that white matter is more severely affected than grey matter in children with FASD (Archibald et al., 2001; Lebel et al., 2008) suggest that alcohol may have a disproportionate effect on myelination (Archibald et al., 2001). While some longitudinal studies suggest that children and adolescents with PAE demonstrate delayed white matter development (Treit et al., 2013), others suggest that children with FASD have reduced white matter and subcortical grey volumes compared to typically developing children but show similar rates of developmental change in most brain regions(Gautam et al., 2015). Children with PAE and more executive difficulties appear to have larger volume increases over time than typically developing children, particularly in the frontal and temporal-parietal regions, suggesting that they may use brain resources differently (Gautam et al., 2015).

'Early vulnerability' theorists have argued that brain insults that occur prenatally or within the first year of life, are particularly detrimental to the development of cognitive functions (V. Anderson et al., 2001). In children with FASD, widespread brain damage occurs prenatally with alcohol impacting on the proliferation of stem cells, leading to a reduction in the generation of new neurons and glial cells, neuronal cell damage or cell death, disorganised cortical architecture, and disruption of mechanisms that mediate cell proliferation, growth, differentiation, and migration, among other adverse neurological outcomes(Petrelli et al., 2018). Therefore, prenatal structural changes in the brain appear to affect the maturational processes of the brain, which continue postnatally (Sowell et al., 2002), in turn affecting the development of cognitive abilities (Stuss, 1992).

Some studies investigating the development of executive abilities in children with FASD suggest that these children are able to acquire some higher cognitive skills as they grow older (Kodituwakku et al., 2006). However, the extent to which these children are able to acquire these skills over time relative to their non-alcohol-exposed peers remains unclear. As discussed above, there is also some evidence that children with FASD display more executive difficulties as they get older (Rasmussen & Bisanz, 2009; Rasmussen et al., 2007; Tamana et al., 2014). This seems to suggest that children with FASD 'grow' into their deficits, that is, that cognitive abilities that should emerge at a particular developmental stage do not develop due to abnormalities that arise in postnatal brain development subsequent to prenatal brain injury (Kolb et al., 2008).

Chapter Three: Aims, Objectives and Hypotheses

Aims

The first aim of this study was to provide a nuanced understanding of how executive function manifests in both alcohol-exposed and typically developing adolescents from a low socio-economic status (SES) community. The broad nature of the executive function construct makes it challenging to understand the relationship between FASD and executive function (Khoury et al., 2015). In addition, an extensive body of literature (discussed in Chapter 2) suggests that poverty has a profound impact on the development of executive function. Given that I am investigating in a low SES community in a LMIC, it is likely that even typically developing children may perform differently on measures of executive function (e.g. exhibit lower performance or display a different profile) compared to children from MHIC, where most studies to date have been conducted. Thus, it was necessary to establish the dimensions of executive function in my study population before comparing the FASD and control groups.

The second aim of this study was to determine whether there is a specific profile of executive function deficits that is characteristic of FASD in this low-SES population. To achieve this, the executive function abilities of a sample of adolescents with a history of prenatal alcohol exposure (the FASD group) were assessed using a range of neuropsychological tests and compared to a sample of typically developing adolescents (the control group).

The third aim was to assess executive function in the FASD and control groups at two time points 18 months apart to apply a developmental lens to our understanding of executive function deficits in FASD. The developmental neuropsychology literature suggests that, in

typically developing children, executive function undergoes rapid development during childhood and early adolescence. By mid-adolescence, most of these skills are fairly well developed, although certain executive function skills continue to develop during late adolescence and early adulthood (Anderson, 2002). However, it is unclear whether executive function has a similar developmental trajectory in children with FASD. There is some evidence that executive function deficits may become more pronounced with age (Rasmussen & Bisanz, 2009); however, no longitudinal studies have been performed to date. This aim addressed this shortcoming in the literature.

The fourth aim was to assess the extent to which the FASD and control groups displayed executive functioning difficulties in their daily lives through the administration of parent and teacher rating scales. Previous studies (e.g., Gross et al., 2015; Nguyen et al., 2014) have suggested that children with FASD may have more difficulties with executive function in their daily lives than what is identified through neuropsychological tests alone. Although several previous studies have used parent-rating scales to examine executive function in children with FASD, relatively few studies have used teacher-rating scales. This is problematic, as the classroom environment may place different demands on children and adolescents than the home environment. In addition, there is evidence that teacher rating scales may be better at discriminating children with FASD from typically developing children (Taylor & Enns, 2019). This aim addressed this shortcoming in the literature and extended previous studies in this area.

The fifth aim was to examine the relationship between neuropsychological measures of executive function and informant (i.e. parent and teacher) ratings of executive function. Previous studies have found low to modest correlations between performance on neuropsychological tests of executive function and parent ratings of executive function in

children with FASD (Gross et al., 2015; Mohamed et al., 2019; Rai et al., 2017). However, to date, the relationship between neuropsychological measures of executive function and teacher ratings of executive function has only been examined in one study (Bernes et al., 2021). This aim addressed this shortcoming in the literature and extended previous studies in this area.

Objectives and Hypotheses

Objective 1: To describe the executive function profile of a sample of typically developing adolescents from a low-SES community.

Hypotheses

1.1 Typically developing adolescents (the control group) from a low-SES community will perform significantly worse on neuropsychological measures of executive functioning compared to international normative data.

1.2 The executive function test scores of the control group will load onto separate factors (i.e. executive function will show simultaneous unity and diversity).

Objective 2: To compare the performance of the FASD and control groups on neuropsychological tests of executive function at two time points 18 months apart (Time 1 and Time 2), using the factors/domains identified in Objective 1.

Hypotheses

2.1 The control group will perform better across all domains of executive function at Time 2 than at Time 1.

2.2 The FASD group will perform better across all domains of executive function at Time 2 than at Time 1.

2.3 The FASD group will perform worse than the control group across all domains of executive function at both Time 1 and Time 2.

Objective 3: To compare the extent of executive function difficulties displayed by the FASD and control groups in their daily lives as rated by parents and teachers.

Hypotheses

3.1 Compared to international normative data, the FASD group will be more likely to obtain scores in the clinically impaired range (defined as *a t* score ≥ 65) relative to the control group on both parent and teacher rating scales.

3.2 Teachers will rate the FASD group as displaying more difficulties with executive function than the control group.

3.3 Parents[1] will rate the FASD group as displaying more difficulties with executive function than the control group.

Objective 4: To investigate the relationship between neuropsychological measures of executive function and executive difficulties as rated by parents and teachers in the FASD and control groups.

Hypotheses

4.1 Neuropsychological measures of executive function will be poor predictors of teacher ratings of executive function in both the FASD and control groups.

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[1] In this dissertation the term "parent" will be used to refer to primary carers, which may include other members of the family (e.g., an aunt or grandmother), foster or adoptive parents, or guardians who provide daily care to the adolescent.

4.2 Neuropsychological measures of executive function will be poor predictors of parent ratings of executive function in both the FASD and control groups.

Chapter Four: Methods

Research Design

This comparative quantitative study documented and compared executive function as measured using neuropsychological tests and behavioural measures (i.e. questionnaires) in adolescents with a history of prenatal alcohol exposure (the FASD group) and a group of typically developing control participants (the control group) at two time points 18 months apart. Thus, the study used a repeated measures design, comparing the performance of the two groups of participants on tests of executive function at approximately age 14 (Time 1) and at 18-month follow-up (Time 2).

Participants

The Study Cohort

Using a purposive sampling strategy (de Vos et al., 2011), the study participants were selected from a well-defined cohort of children from a community in the Western Cape Province of South Africa. This community is situated in an agricultural and wine production region of the Western Cape and consists of a town of approximately 35, 000 people and surrounding rural areas with about 15,000 people located about a one-hour drive from Cape Town. Historically, farmers distributed wine to workers in partial payment for labour as part of a practice call the "Dop" system. Although outlawed decades ago, the legacy of the *Dop* system remains, with many sub-segments of the Western Cape population engaging in frequent, heavy, episodic (i.e. binge) alcohol consumption, especially on holidays and weekends (May et al., 2007; May et al., 2019).

The cohort from which the sample for the present study was recruited was previously identified in 2002 through a National Institutes of Health (NIH)-funded epidemiological study that used a two-tier active case ascertainment approach to identify children with FAS and partial FAS (pFAS) using the revised US Institute of Medicine diagnostic criteria (Hoyme et al., 2005). The methodology of the epidemiological study is described in detail by May et al. (2007) and illustrated below (see Figure 2), and will only be briefly summarised here.

All children in grade 1 (i.e. the first year of schooling in the South African educational system) enrolled in 12 of 13 schools in the community who had parental consent to participate (n = 818) underwent Tier I screening where height, weight, and head circumference were measured. Children who were at or below the 10^{th} percentile on head circumference and/or on both height and weight (n = 306) were referred for a complete physical examination (Tier II), where they were examined independently by two paediatric dysmorphologists (May et al., 2007).

Based on the dysmorphology evaluation, a preliminary diagnosis of either FAS, deferred, or not-FAS was assigned. Children with the classic FAS phenotype (i.e. two or more of the facial features characteristic of FAS, prenatal and/or postnatal growth retardation, and evidence of deficient brain growth as measured by occipitofrontal head circumference (OFC) < 10^{th} percentile) were assigned a preliminary diagnosis of FAS. Children with a deferred diagnosis had some anomalies typically associated with FAS but required further assessment in the form of maternal interviews and cognitive assessment for final diagnosis (May et al., 2007).

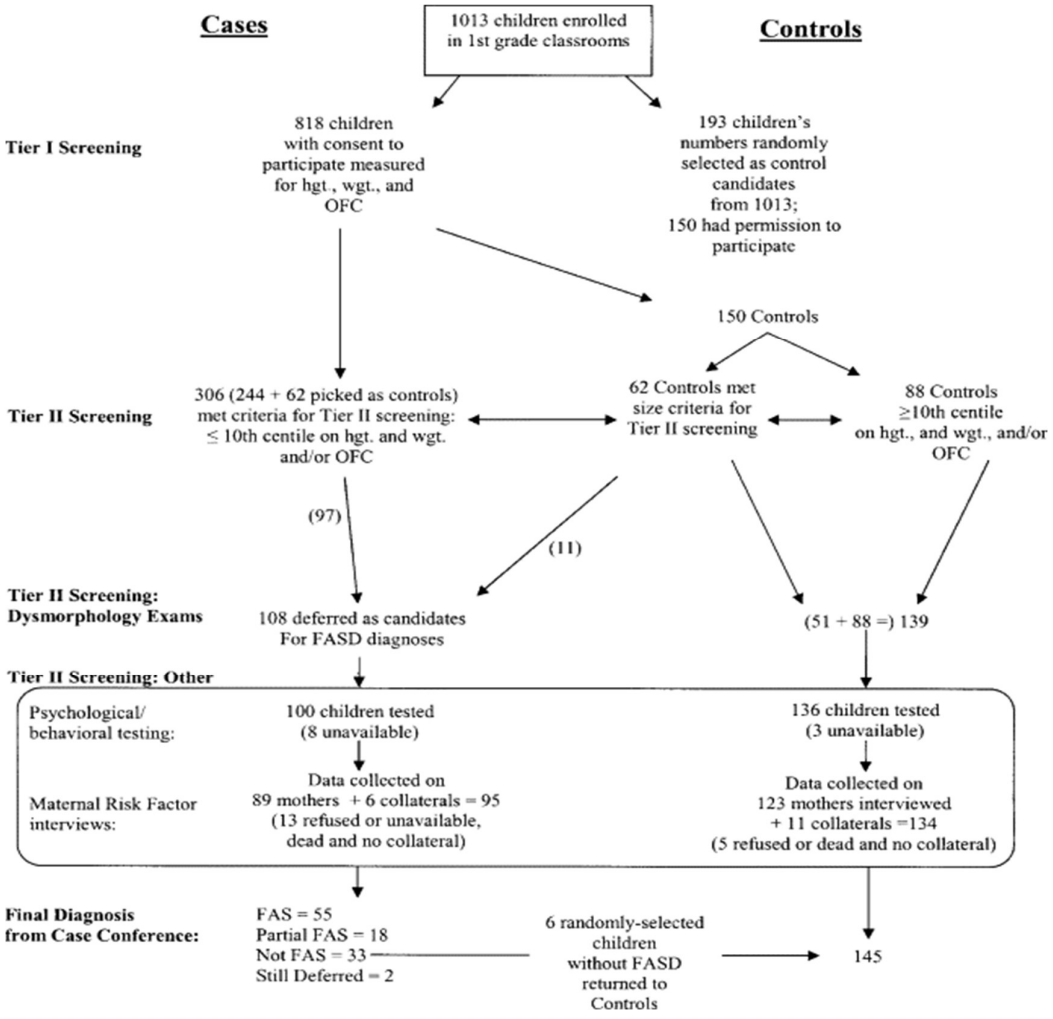
In total, 193 children were randomly selected as possible controls from lists of all grade 1 students enrolled in the 12 schools involved in the study. Parental consent to

participate could be obtained for 150 children. Sixty-two children had height, weight, or OFC below the 10th percentile and therefore met the criteria for Tier II dysmorphology examinations. After Tier II screening, 51 children were found not to meet criteria for FAS or pFAS and were returned to control status (May et al., 2007).

Children with a preliminary diagnosis of FAS or deferred (n = 100) and control participants (n = 133) underwent cognitive testing as well as an evaluation of their behaviour. In addition, their mothers were interviewed to obtain information about alcohol, tobacco, drug use during pregnancy, and other prenatal risk factors. A final diagnosis of FAS, pFAS, or not-FAS was made after case conferences were held for each child, considering the information obtained during the dysmorphology exam, developmental testing, and maternal interview (May et al., 2007).

Figure 2

Sampling Methodology of the Epidemiological Study.



Note. From "The epidemiology of fetal alcohol syndrome and partial FAS in a South African community" by P.A. May, J.P. Gossage, A. Marais, C.M. Adnams, H.E. Hoyme, K.L. Jones, L.K. Robinson, N.C.O. Khaole, C. Snell, W.O. Kalberg, L. Hendricks, L. Brooke, C. Stellavato, D.L. Viljoen, 2007, *Drug and Alcohol Dependence*, 88 (2-3), p. 262. (https://doi.org/10.1016/j.drugalcdep.2006.11.007). Copyright 2006 by Elsevier. Reprinted with permission.

Because the sample is well defined, much demographic information is available on the participants and their mothers. Social and demographic information for this cohort is reported in detail in May et al. (2008). All mothers were Coloured (i.e. people of mixed ancestry from intermarriage of black African populations, white Europeans, and Asians) or Black and would therefore have been impacted by the institutionalised racial segregation and systemic inequalities of Apartheid and its legacies. Mothers of children who received a FASD diagnosis were more likely to live in a rural area during the index pregnancy (71.2% for FAS and 47.1% for PFAS) compared to controls (33.8%). Mothers of children with FAS had significantly lower levels of educational attainment (4.6 years) compared to controls (8.1 years). Maternal weekly income was low for the entire sample, although mothers of children with FAS earned significantly less (94 Rands or approximately 15 US Dollars at the time May et al., 2008 collected their data) than mothers of control participants (211 Rands or approximately 34 US Dollars). These demographic factors led the authors to note that this sample of woman has "fewer social resources than women in more developed populations without a legacy of discrimination; but when compared to controls, mothers of FAS and PFAS children were even lower SES and had fewer social resources" (May et al., 2008, p. 749).

Study Sample

The present study is embedded in a larger study "A Multisite Neurobehavioral Assessment of Fetal Alcohol Spectrum Disorders (5UO1 AA014834-05)" which forms part of a National Institutes of Alcoholism and Alcohol Abuse (NIAAA)-funded international consortium of studies, the Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD). The University of Cape Town is a partner in the consortium and the multisite neurobehavioural study that included participants from the above-mentioned cohort of children. I obtained permission to use the South African data of the multi-site neurobehavioural study for the present study from the principal investigator, Dr Sarah Mattson (San Diego State University), and the South African site co-principal investigators, Dr Phillip May (University of Albuquerque, New Mexico), and Prof. Colleen Adnams (University of Cape Town).

Figure 2 illustrates the recruitment flow for the present study. Of the 220 children that made up the cohort identified by May et al. (2007), I was able to contact and recruit 119 participants between the ages of 13 and 16. Of these participants, 48 were previously diagnosed with either FAS or pFAS, whereas 71 were classified as not-FAS or controls.

Of the 71 participants classified as not-FAS/controls, eight had a documented history of more than minimal prenatal alcohol exposure, while six had a history of minimal exposure. Minimal exposure was defined as equal or less than one drink per week on average and never more than two drinks on any occasion. Those with more than minimal exposure were typically heavily exposed (i.e. more than four drinks per occasion at least once a week or more than 13 drinks per week). In line with the selection criteria for the multi-site neurobehavioural study (see Mattson et al., 2010 for a full description of the methods used in that research project), the eight participants with a history of heavy alcohol exposure (i.e.

more than minimal) were added to the FASD group, while those with minimal exposure were retained in the control group. One participant in the FASD group was excluded because of a lack of information regarding the extent of their prenatal exposure to alcohol.

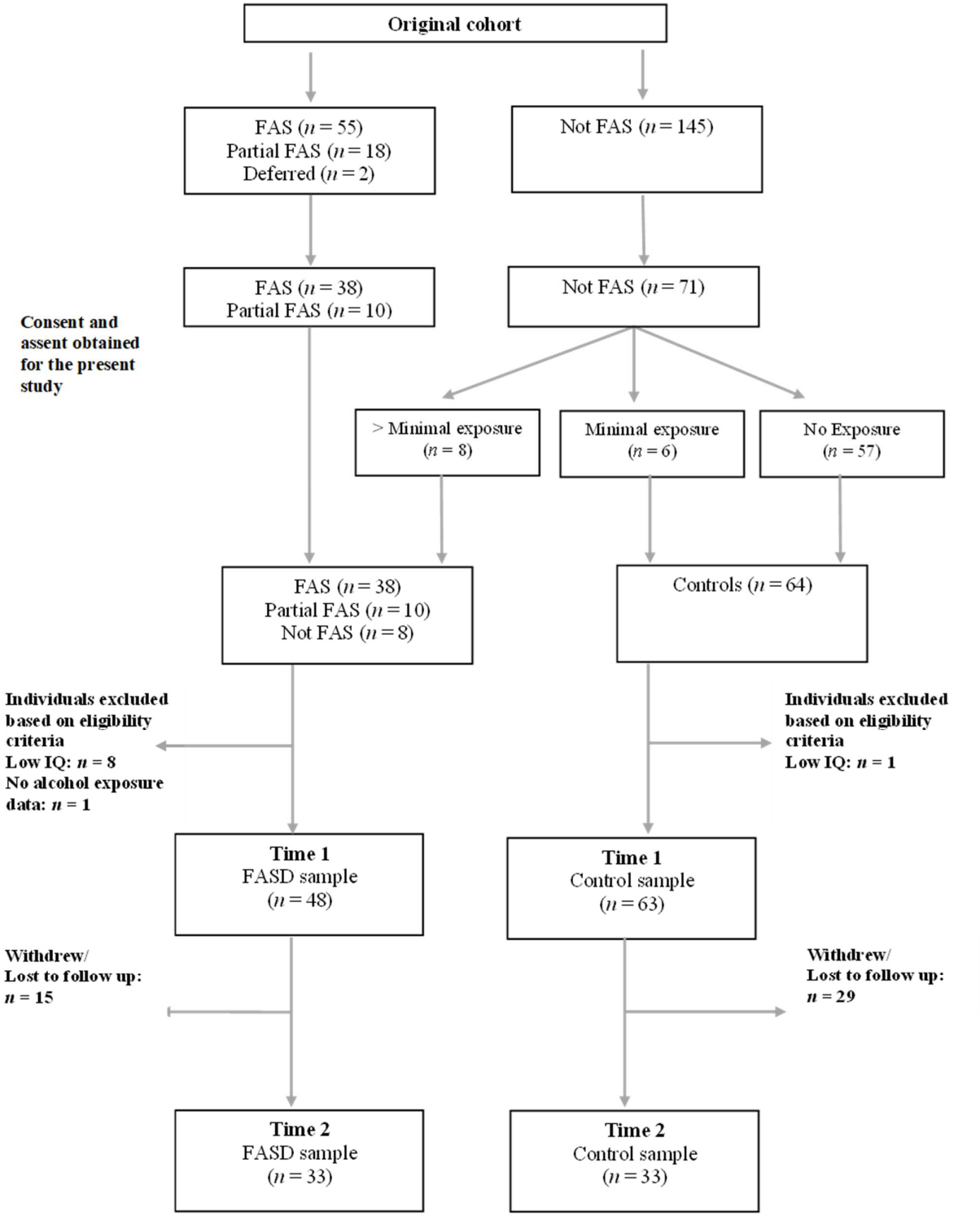
The intellectual functioning of the cohort of children from which the sample for the present study was recruited was previously assessed at age nine using the Leiter International Performance Scale Revised (Leiter-R; Roid & Miller, 1997), a non-verbal measure of intelligence. Individuals with IQ scores below 55 were excluded from the present study. This ensured that all participants were likely to understand the study procedure and complete the neuropsychological tests. Based on this criterion, I excluded nine participants from the study, eight from the FASD group and one from the control group. None of the participants were known to have a psychiatric or neurodevelopmental disorders other than FASD or had uncorrected visual or hearing disorders that would interfere with their test performance.

The final sample was made up of 110 participants: 48 in the FASD group and 62 in the control group. Descriptive statistics for the sample at Time 1 (T1) are provided in Table 1. The FASD and control groups were matched for age, gender, and handedness. All participants spoke Afrikaans as their first language and were of Coloured decent.

All participants were invited to participate in the longitudinal component of the study and to return for neuropsychological testing 18 months after the initial assessment (Time 2). During the interim period, 44 participants (15 FASD and 29 controls) withdrew or were lost to follow-up. The final sample at Time 2 (T2) comprised of 33 adolescents in the FASD group and 33 in the control group (see Table 3 and Table 4 for descriptive statistics).

Figure 3

Recruitment of Participants and Sample Size for the Present Study at T1 and T2



Tests and Outcome Measures

All the measures used in the present study form part of a larger battery of neuropsychological tests compiled by Dr Mattson and CIFASD collaborators to assess children's basic level of intellectual functioning and specific cognitive domains such as attention, language, visuospatial function, executive function, and behaviour across multiple sites (Mattson et al., 2010). The full battery of tests took approximately six hours to administer.

Data for the present study was derived from participants' performance on subtests of the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001), the Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition, 2014), and information obtained from the Behavior Inventory of Executive Function (BRIEF; Gioia et al., 2000). It should be noted that none of the measures has been adapted and validated for the South African population. Nevertheless, considering the absence of suitably adapted and standardised assessment tools and the fact that this study was part of a larger international multi-site investigation requiring direct comparisons of outcomes, these tools were deemed the most suitable available options.

As a fully bilingual Afrikaans and English speaker, I translated all the test materials and questionnaires into Afrikaans. Test instructions and questions were subsequently back-translated by a bilingual research assistant and any discrepancies were reconciled.

Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997)

Although children's general intellectual ability was measured using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) as part of the multi-site study, I decided not to use this data, as preliminary analysis suggested that, in keeping with previous

studies examining the performance of disadvantaged South African samples on the Wechsler IQ tests (Shuttleworth-Edwards et al., 2004; Van der Merwe, 2008), both groups performed very poorly on this test. Controlling for IQ using the WISC-IV may, therefore, have obscured any differences that might be observed between the FASD and control groups. Instead, I obtained data pertaining to participants' general intellectual functioning from a previous CIFASD study ("Phase 1 of A Multisite Neurobehavioral Assessment of Fetal Alcohol Spectrum Disorders [2U01AA014834-04]") on the same sample of children when they were approximately nine years old. That study used the Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997) to measure nonverbal intelligence.

The Leiter-R is an individually administered test designed to assess fluid reasoning and visualisation. The Leiter-R was normed on 1,719 individuals aged 2 to 20. It provides a full IQ score which is scaled as a standard score with a mean of 100 and a standard deviation of 15 (Roid & Miller, 1997). Several of the subtests that form part of the Weschler IQ test batteries are known to have high cultural content; that is, an adequate performance requires specific knowledge or experience of Western culture (Cathers-Schiffman & Thompson, 2016; Mushquash & Bova, 2007). In contrast, most Leiter-R subtests are low in cultural content, making this test more suitable for children from non-English speaking backgrounds (Cathers-Schiffman & Thompson, 2016).

Delis-Kaplan Executive System (D-KEFS; Delis et al., 2001)

The D-KEFS was designed to assess several domains of executive function. The D-KEFS was standardised in the United States on over 1,700 children and adults aged 8 to 89 years. Given that no normative data exists for the South African population, raw scores instead of scaled scores were used to compare the performance of the FASD group with that of the control group. The D-KEFS has been used in several paediatric clinical populations

(Parrish et al., 2007; Pulsipher et al., 2009; Wodka, Loftis, et al., 2008; Wodka, Mostofsky, et al., 2008), including FASD samples from South Africa (Carter et al., 2016; Kodituwakku et al., 2006) and North America (Mattson et al., 1999; Rasmussen & Bisanz, 2009; Schonfeld et al., 2001).

I used six subtests of the D-KEFS (described in detail below); the administration time was approximately one hour:

i. *Trail Making Test.* This test consists of five tasks, four of which predominantly measure underlying non-executive abilities, including visual attention (Visual Scanning), basic numerical processing (Number Sequencing), fundamental verbal skills (Letter Sequencing), and fine motor speed (Motor Speed). The primary executive function task is the Number-Letter Switching Condition. This task requires the examinee to switch back and forth between connecting numbers and letters in sequence and measures cognitive flexibility (Delis et al., 2001). The outcome variables are completion time for each condition and the total error score for the Number-Letter Switching Condition (Switching Total Errors). The Switching Total Error score includes sequencing errors (i.e. when an examinee connects an item that is out of sequence within the correct set), set-loss errors (i.e. when the examinee fails to switch from one set of symbols to another), and time-discontinue errors (when the examinee fails to connect one or more items because the time limit has elapsed) (Delis et al., 2001).

ii. *Verbal Fluency Test.* This test measures verbal fluency and generativity (Delis et al., 2001). It consists of three conditions where the examinee is required to either generate words that begin with a particular letter (Letter Fluency Condition), words from specific semantic categories (Category Fluency Condition), or to alternate between

generating words from two different semantic categories (Category Switching Condition) within a time limit. For the letter fluency task, the letters BAS were used instead of FAS, as the letter F is not common in the Afrikaans language, in line with previous South African studies (Kodituwakku et al., 2006). The outcome variables are the total number of correct words generated for each condition and the total number of errors across all three conditions (Set Loss Errors, Repeat Errors). A set loss error is any error that violates the rules of the condition. A repeat error is a response that is repeated within the 60 seconds of a trial (Delis et al., 2001).

iii. *Design Fluency Test.* This test consists of three conditions: Filled Dots, Empty Dots, and Switching. The examinee is presented with rows of boxes, each containing an array of dots, and is required to draw different designs using only four lines to connect the dots within a time limit. Filled Dots provides a basic measure of nonverbal fluency and productivity. Empty Dots measures nonverbal fluency and response inhibition. Switching measures both nonverbal fluency and cognitive flexibility (Delis et al., 2001). The outcome variables are the total correct designs produced for each condition and the total number of errors across all three conditions (Set-Loss Errors, Repeat Errors). A set-loss error is any error that violates the rule of the condition. A repeat error is any design that is repeated within a given condition (Delis et al., 2001).

iv. *Color-Word Interference Test.* This test has two non-executive conditions that measure basic naming (Color Naming) and reading (Word Reading) speed and accuracy. The first executive measure of this test (Inhibition) measures the examinee's ability to inhibit a prepotent response, and requires the examinee to inhibit an overlearned verbal response (reading the words) to generate a conflicting response (naming the colour of the ink in which the words are printed) (Delis et al., 2001). The second executive measure of this test (Inhibition/Switching) measures both inhibition

and cognitive flexibility, and requires the examinee to switch between naming the colour of the ink and reading the word when it is inside a box (Delis et al., 2001). The outcome variables are completion time for each condition and total errors for the two executive measures (Inhibition Total Errors, Inhibition/Switching Total Errors). The Total Error scores for both the Inhibition and Inhibition/Switching conditions include self-corrected and uncorrected errors.

v. *Twenty Questions Test.* In this test, the examinee is presented with a stimulus page containing pictures of 30 objects. The examiner preselects one of the objects (the target), and the examinee must ask as few yes/no questions as possible to identify the target. Four items are administered. The test measures problem-solving, verbal and spatial concept formation, and the ability to incorporate the examiner's feedback to formulate more efficient yes/no questions (Delis et al., 2001). Outcome variables are the Initial Abstraction Score, Total Questions Asked, Total Repeat Questions and Total Set Loss Questions. The Initial Abstraction Score is based on the number of items that the examinee eliminates, with their first question summed across all four items. The Total Questions Asked score is based on the number of questions asked to identify the target for each item summed across the four items. The Total Repeat Questions score reflects the number of times an examinee repeats a question (i.e. asks a question referring to the same object) within an item summed across all four items. The Total Set Loss Questions score reflects the total number of times an examinee asks questions that violate the rules of the task summed across all four items.

vi. *Tower Test.* This task requires the examinee to move discs of various sizes across three pegs to build a designated tower in the fewest number of moves possible, while simultaneously following several rules. It taps a variety of executive functions, such as planning, rule learning, inhibition, and the ability to establish and maintain a

cognitive set (Delis et al., 2001). The test consists of nine items of increasing levels of difficulty. The outcome variables are the Total Achievement score, Move Accuracy Ratio and Total Rule Violations score. The Total Achievement Score provides a global measure of performance on this task. The Move Accuracy Ratio indicates the degree to which an examinee employs effective strategies to construct the towers. The Total Rule Violations score represents the total number of times the examinee violated the rules of the task across all the items (Delis et al., 2001).

Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition, 2014)

The CANTAB is a computerised measure of cognition. Although it was initially developed to assess cognitive function in the elderly and neurologically impaired adults, it has since been used in several studies examining the development of executive function in typically developing children (De Luca et al., 2003; Luciana & Nelson, 1998) and children with developmental disorders, such as ADHD (Claesdotter et al., 2018; Fried et al., 2015) and FASD (Green et al., 2009; Moore et al., 2021).

The CANTAB was run on a Paceblade Slimbook with a built-in touch screen running the Windows XP operating system. The examinee interacts with the system by touching the touch screen with the tip of the index finger of their dominant hand. For certain tasks (e.g. Choice Reaction Time, Simple Reaction Time), the examinee also uses a press pad as an input device. I used six subtests of the CANTAB (described in detail below); the administration time was approximately 50 minutes.

i. *Motor Screening (MOT).* This test screens for visual, movement, and comprehension difficulties, and is also used to familiarise the examinee with the CANTAB user

interface. A series of crosses are displayed at different locations on the screen. The examinee is required to touch the crosses when they flash pink and green. The crosses disappear when touched correctly. Outcome variables include the Mean Latency and Mean Error scores. The Mean Latency score reflects the time taken by the examinee to touch the cross after it appears. The Mean Error score is a measure of the accuracy of an examinee's pointing (Cambridge Cognition, 2014).

ii. *Big-Little Circle.* This test is also used as a screening and familiarisation task to prepare examinees for the Intra-Extra Dimensional Set Shift (IED) test. It tests comprehension, learning, and reversal. The examinee is presented with a series of pairs of circles, one large and one small. The examinee is instructed to first touch the small circle and then, after 20 trials, to touch the larger circle for a further 20 trials (Cambridge Cognition, 2014). Outcome variables include the Mean Correct Latency, Total Correct, and Total Error scores. The Mean Latency score indicates how quickly the examinee touched the correct stimulus. The Total Correct score is the total number of correct responses. The Total Error score is the number of times the examinee made an incorrect response (Cambridge Cognition, 2014).

iii. *Intra-Extra Dimensional Set Shift (IED).* This test of executive function assesses rule acquisition and attentional set shifting. It uses patterns (colour-filled shapes and white lines) that are displayed as either simple or compound stimuli. The examinee must use feedback to work out a rule that determines which stimulus is correct. After six correct responses, the stimuli and/or rules change. Initially, the task involves simple stimuli that are made up of just one of the dimensions (e.g. two white lines that differ in shape). Later in the task, compound stimuli are used (e.g. white lines overlaid on coloured shapes). The shifts in the rule are initially intra-dimensional (i.e. the coloured shapes remain the only relevant dimension), and later extra-dimensional (i.e.

white lines become the relevant dimension). The outcome variables include Pre-ED Errors, EDS Errors and Total Errors Adjusted. Pre-ED Errors records the number of errors made prior to the extra dimensional shift of the task. Errors are defined as instances in which the examinee fails to select the stimulus that is compatible with the current rule. EDS Errors are errors made in the extra-dimensional stage of the task. Total Errors Adjusted is a measure of the examinee's efficiency in attempting the task (Cambridge Cognition, 2014).

iv. *Spatial Working Memory (SWM).* This test measures visual working memory and strategy use. The test begins with several coloured squares that can be "opened" by being touched to search for a blue token. There is a black column that serves as a "container" for the blue tokens. If a square contains a token, the examinee moves it to the "container" in the corner of the screen. In each trial, each square contains only one blue token. For the most efficient performance, the examinee must remember where they had previously searched and found a token. The task becomes increasingly difficult with an increase in the number of boxes and tokens between trials. Outcome variables include a Strategy score, a Between Error score and a Within Error score. The Strategy score refers to the overall degree to which the examinee employed an efficient strategy to complete the task. Between Errors are defined as occasions upon which the examinee revisits a box in which a token has previously been found. Within Errors are defined as the number of errors made within a search, that is, the number of times the examinee revisits a box already found to be empty during the same search (Cambridge Cognition, 2014).

v. *Choice Reaction Time (CRT).* This is a test of attention that also measures response speed in a simple two-choice paradigm. An arrow-shaped stimulus is displayed on either the left or the right side of the screen. The examinee is required to press the left-

hand button on the press pad if the stimulus is displayed on the left-hand side of the screen, and the right-hand button if the stimulus is displayed on the right-hand side of the screen (Cambridge Cognition, 2014). The outcome variables include the Mean Latency, Total Commission Errors, and Total Omission Errors scores. The Mean Latency score is a measure of response speed. The Total Commission Errors score indicate the number of times the examinee pressed the button too soon. The Total Omission Errors score indicates the number of times the examinee pressed the button too late or not at all (Cambridge Cognition, 2014).

vi. *Simple Reaction Time (SRT).* The SRT is also a test of attention and measures speed of response to a single stimulus. The examinee is required to press a button on the press pad as soon as they see a square appearing on the screen. The outcome variables include Mean Latency, Total Commission Errors, and Total Omission Errors. As in the case of CRT, the Mean Latency score is a measure of response speed; Total Commission Errors indicate the number of times the examinee pressed the button too soon, and Total Omission Errors indicate the number of times the examinee pressed the button too late or not at all (Cambridge Cognition, 2014).

Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000)

The BRIEF is an 86-item questionnaire designed to be completed by parents and teachers of school-age children. The completed questionnaire provides a profile of a child's executive function and behaviours at home, school, and in social environments (Gioia et al., 2000). Items are rated on a three-point scale (*never*, *sometimes*, and *often*), with higher scores reflecting more severe executive difficulties in daily life. Both the parent (BRIEF Parent) and teacher (BRIEF Teacher) forms were standardised in the United States for children aged 5 to 18 years. Raw scores are converted to *t*-scores ($M = 50$, SD = 10). *T*-scores equal or greater

than 65 are considered to fall within the clinically impaired range (Gioia et al., 2000). Both raw and *t*-scores were used in different analyses in the present study.

Information obtained from behavioural inventories such as the BRIEF may be a useful addition to that obtained from neuropsychological measures of executive function because they allow for a better prediction of the child's everyday behaviour (Baron, 2000). The BRIEF has been used in several clinical populations, including children and adolescents with autism (Chan et al., 2009), ADHD (Toplak et al., 2009), and FASD (Gross et al., 2015; Rai et al., 2017; Rasmussen et al., 2007; Taylor & Enns, 2019). A recent systematic review found that the BRIEF is one of the most rigorously validated measures of executive function for use in LMICs, although its cross-cultural validity has not yet been established (Kusi-Mensah et al., 2022).

The outcome variables include an overall score, the Global Executive Composite score (GEC), two index scores, the Behavioral Regulation Index (BRI) and Metacognition Index (MI), and eight clinical scales (Gioia et al., 2000). I describe the purpose of each clinical scale in more detail below.

i. *Inhibit scale.* Assesses inhibitory control and impulsivity. Children with elevated scores on this scale typically have difficulty resisting impulses and considering the consequences before acting (Gioia et al., 2000).

ii. *Shift scale.* Assesses the ability to move freely from one situation, activity, or aspect of problem to another as the situation demands, to transition from one task to another, and to solve problems flexibly. Children with elevated scores on this scale may get stuck on problems or exhibit marked resistance to change (Gioia et al., 2000)

iii. *Emotional Control scale.* Assesses the ability to regulate emotional responses appropriately. Children with elevated scores on this scale may overreact to events and display frequent episodes of emotional dysregulation (Gioia et al., 2000)

iv. *Initiate scale*. Assesses the ability to start tasks or activities and generate ideas independently. Children with elevated scores on this scale may have difficulty getting going on tasks without adult support (Gioia et al., 2000).

v. *Working Memory scale*. Assesses the ability to hold information in mind while completing a task. Children with elevated scores on this scale may appear forgetful, struggle to retain instructions, or lose track of what they are doing (Gioia et al., 2000).

vi. *Plan/Organize scale*. Assesses the ability to anticipate future events, set goals, and develop steps to complete tasks systematically. Children with elevated scores on this scale may underestimate the time required to complete a task or the difficulty level of the task. They may also approach tasks in a haphazard manner (Gioia et al., 2000)

vii. *Organization of Materials scale*. Provides an indication of the child's ability to keep their workspace, play area, or belonging tidy (Gioia et al., 2000).

viii. *Monitor scale*. Assesses the child's ability to assess their performance during or after finishing a task to ensure that the goal has been attained and to keep track of the impact of their behaviour on others (Gioia et al., 2000).

Assessment Procedure

Informed consent was obtained from the parents/guardians and assent from the participants (see Appendix) prior to the start of data collection. The participants were then scheduled for an individual neuropsychological assessment session, which took place at a research office rented by the University of Cape Town specifically for this purpose. Each participant was collected from their home or school and transported by a fieldworker to the

testing venue on the day of the appointment. Participants were offered an incentive (gift voucher, cap, and athlete's water bottle or stationary) to the value of 70 Rands (approximately 5 US Dollars) after the assessment session to thank them for their time.

Participants' parents and teachers were then asked to complete the BRIEF to obtain qualitative information about their executive function at home, at school, and in social situations. Teachers were given instructions on completing the BRIEF (and other questionnaires, which formed part of the multi-site neurobehavioural study) in a group training session held at each of the schools from which the children were recruited. The teachers then completed the questionnaires in their own time, after which they were collected from the school.

Given the relatively low level of education of the parents, which could have impacted their ability to understand and accurately complete the study questionnaires, I conducted semi-structured interviews with parents and caregivers to complete the BRIEF. A driver collected the parent/caregiver from the home or place of work and transported them to the research office, where an experienced research assistant administered the questionnaires. Parents/caregivers were compensated with a food hamper to the value of R70 (i.e. approximately $5) for their time.

All participants were invited to participate in the longitudinal component of the study and return for neuropsychological testing 18 months after the initial assessments. Parent and teacher questionnaires were also re-administered at this time. Although both cognitive and brain development are known to slow down during adolescence (relative to the rapid development that takes place in childhood), I felt confident that the 18-month follow-up would allow for some maturational changes to take place. In addition, this interval was

selected because it would allow for any practice effects on neuropsychological measures to dissipate.

Data Management Procedure

Neuropsychological testing was conducted by me or by research assistants who were trained and supervised by me. All test administrators were blinded to the participants' diagnoses during the data-collection phase. Scoring of neuropsychological tests was reviewed and checked by me or by a research assistant who did not perform the assessments. The data was then entered into scoring software for the D-KEFS and BRIEF. The scoring software output reports, including those obtained for the CANTAB, were electronically imported into the Central Repository, an online database for CIFASD.

Ethical Considerations

Ethical Approval

This study was nested in a larger study, "A Multisite Neurobehavioral Assessment of Fetal Alcohol Spectrum Disorders (5UO1 AA014834-05)" for which ethical approval was granted by the University of Cape Town Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (HREC Ref 292/2010), and the Western Cape Education Department.

Informed Consent

Informed consent was obtained from the parents or guardians of all participants prior to the administration of any tests or interviews. In addition, assent was obtained from all participants (see Appendix).

Confidentiality

Tests and questionnaires were administered one on one in a confidential manner. The confidentiality of participants' results on neuropsychological and intellectual tests was protected. Participants' identities were protected, and confidentiality was maintained by assigning subject ID numbers that were used to identify individual participants' test data. All identifying information was removed from the collected material. Some neuropsychological testing sessions were recorded for reliability purposes. The video recordings were kept in a secure location and were treated in a confidential manner. The collected data was entered into a database with ID numbers, sex, and date of birth as identifiers, and all identifying information, as well as paper and pencil data and CDs storing video data, were kept in a locked storeroom at the University of Cape Town. As mentioned above, the present study was nested in a multisite neurodevelopmental study. Aside from myself, only one of the South African site principal investigators, Dr Colleen Adnams, had access to the storeroom.

Potential Risks and Benefits

The potential risks to subjects participating in the study were few and minor. Participants may have experienced mild test-taking anxiety during the administration of neuropsychological tests. They may also have experienced mild discomfort at having their responses to test material videotaped. Participants could, at any time, inform the researcher of any discomfort pertaining to videotaped responses and refuse to record their responses. Parents may have experienced mild discomfort when answering personal questions about their children's behaviour. Participants and their parents were free to withdraw from the study at any time without having to give a reason, and without this affecting any possible future treatment. If participants or their parents reported any significant social and emotional

problems that were unrelated to their participation in the study, they were referred to appropriate social or psychological services in their community.

Potential benefits included feedback to the child's school regarding their cognitive function, which was provided after permission to do so was obtained from the parent or guardian of the child. The school psychologist or learner support teacher at the relevant school was provided with a short report regarding each child's general cognitive function to assist in the planning of long-term school placement. Parents were also given a copy of the report. The benefit to society is a more detailed understanding of the effects of prenatal alcohol exposure on the development of executive function.

Statistical Analysis

All data was downloaded from the Central Repository, after which it was checked for any missing items. All data analyses were performed using SSPS (Version 25). For measures taken at T1 and T2, descriptive statistical analysis of all data was performed, and measures of central tendency (mean and median) and dispersion (range, standard deviation, and variance) were calculated for all variables. Boxplots for all continuous predictor variables (age, non-verbal IQ, and maternal level of education) were constructed to detect outliers that may have influenced the measures of central tendency.

For the inferential statistics that followed, the alpha level was set at 0.01 (unless otherwise stated) instead of the typically used 0.05 level to minimise the possibility of Type 1 error, given the large number of variables being examined. Cohen's *d* was used as an estimate of the effect size for parametric data, Cohen's *r* as an estimate of effect size for non-parametric data and φ as an estimate for the Chi-square (χ^2) analyses.

Before testing the hypotheses listed in Chapter 3, the sample was characterised by conducting several statistical analyses of between-group differences in demographic variables at T1 and T2. Depending on whether the data met the assumptions underlying parametric statistical analysis, either *t*-tests or Mann-Whitney *U* tests were used.

Testing hypothesis 1.1

To obtain a better understanding of how this sample differs from international samples in terms of performance on executive function tests, single-sample *t*-tests were used to compare the performance of the control group on the subtests of the D-KEFS and CANTAB, which have published norms.

Testing hypothesis 1.2

Several *t*-tests were used to compare the performance of the FASD and control groups on those subtests of the D-KEFS and CANTAB which predominantly measure baseline (i.e. non-executive) abilities. This was done to determine which measures of executive function would be most useful in this sample and to exclude measures where poor non-executive abilities (e.g. reading skills) might impact the results obtained. Raw scores instead of standard scores were used, as the D-KEFS and CANTAB are not normed for the South African population, and the use of standardised scores might have obscured any group differences. When significant differences between the performance of the FASD and control groups were found on these non-executive measures, tests were excluded from further analysis.

I then performed a Principal Component Analysis (PCA) with orthogonal rotation (varimax) to reduce the number of cognitive variables and to examine the underlying components/domains of executive function in the control group. Only data obtained from control participants at T1 was used for the PCA, as novel situations are more likely to elicit

the construct of executive function. In addition, data collected at T1 would not be contaminated by practice effects (which may be the case for data collected at T2). I only used data from control participants because the aim was to obtain an understanding of the components of executive functioning domains in typically developing adolescents prior to comparing the two groups. Raw scores were used instead of standard scores because neither the D-KEFS nor the CANTAB is normed for the South African population.

Testing hypotheses 2.1, 2.2, and 2.3

For each factor, a composite score was created by averaging the z-scores of the tests that loaded on the respective factor. A repeated-measures factorial analysis of covariance (ANCOVA; 2 x 2) was performed using group (FASD, Control) and time (T1, T2) as independent variables, and the composite executive function scores as dependent variables. The sample size used for the ANCOVA analysis was $n = 33$ per group, as some children were lost to follow-up and therefore only had data at T1. Non-verbal IQ (as measured by the Leiter-R) and maternal level of education were used as covariates. It is appropriate to control for IQ because some executive abilities have been found to be directly affected by IQ impairments (Connor et al., 2000). Maternal level of education was used as a proxy to control for SES. Whenever non-verbal IQ and/or maternal level of education were found to significantly impact the results, the influence of that covariate was statistically controlled for. Partial eta squares (η^2) were used to estimate effect size.

Testing hypothesis 3.1

To allow for direct comparison with previously published studies, the severity of executive difficulties as rated by parents and teachers on each of the eight clinical scales, the two index scores (BRI, MI), and the GEC of the BRIEF Teacher and BRIEF Parent were

determined through comparison with international normative data. Participants with *t*-scores above 65 were classified as falling in the clinically impaired range. A series of Chi-square analyses were performed to compare the FASD group with the control group on each dependent variable (i.e. the BRI, MI, GEC, and eight clinical scales).

Testing hypotheses 3.2 and 3.3

A repeated-measures factorial analysis of covariance (ANCOVA; 2 x 2) was planned, using group (FASD, Control) and time (T1 or T2) as independent variables, and scores on each of the eight clinical scales and the GEC of the BRIEF Teacher and BRIEF Parent as dependent variables. However, behavioural data obtained from the BRIEF questionnaires was only analysed at T1 because the sample size at T2 was smaller than at T1, and there was numerous missing data (especially for the BRIEF Teacher). For example, BRIEF Teacher data was only available for 14 of the original 48 children in the FASD group and for 17 of the original 62 control participants. Separate one-way ANCOVAs were therefore performed using prenatal alcohol exposure (FASD, Control) as independent variables and scores on each of the clinical scales and the GEC as dependent variables. Raw scores instead of *t*-scores were used, as the BRIEF is not normed for South African children, and the use of standardised scores might have obscured any group differences. Non-verbal IQ (as measured by the Leiter-R) and maternal level of education were used as covariates. Partial eta squares (η^2) were used to estimate effect size.

Testing hypotheses 4.1 and 4.2

A series of 16 Backward linear regressions investigated whether composite cognitive scores were significant predictors of behaviour (as measured by raw scores on the eight

clinical scales of the BRIEF Teacher and Parent) in both the FASD and control groups separately.

Chapter Five: Results

Introduction

Section 1 (Sample Characteristics) of this chapter describes the sample characteristics at both Time 1 (T1) and Time 2 (T2). In Section 2 (The Executive Function Profile of Typically Developing Children from a Low SES Community), the performance of the control group is compared to international normative data to explore how typically developing South African children from a low SES background perform on tests of executive function. In addition, the results of a series of analyses to reduce the number of cognitive test score variables are reported. These results include: (a) analyses comparing the performance of the FASD and control groups on those tests that had non-executive measures to exclude measures where poor non-executive abilities might affect the results obtained; and (b) a PCA using data obtained from control participants only to exclude redundant variables and reduce the number of remaining variables into underlying domains of executive function. In Section 3 (Group Differences and Development: Neuropsychological Measures), composite executive function scores are calculated for both the FASD and control groups at both T1 and T2 using the results of the factor analysis, and subsequently, the performance of the FASD and control group is compared. In Section 4 (Group Differences: Behaviour Rating Scales), the results of several analyses comparing the FASD and control groups on the BRIEF are reported. This includes: (a) the results of several Chi-square analyses comparing the frequency with which the FASD and control groups had *t*-scores in the clinically impaired range on the BRIEF Parent and Teacher forms; and (b) the results of several separate one-way ANCOVAs comparing the FASD and control groups using BRIEF raw scores. In Section 5 (Relationship between Neuropsychological Measures of Executive Function and the BRIEF), a series of correlations and regressions explores the relationship participants' performance on

neuropsychological measures of executive function and parent and teacher ratings of executive function.

Sample Characteristics

Sample Characteristics at T1

Demographic data. Table 1 presents descriptive statistics for the sample at T1. There were no significant between-group differences in terms of age, sex, or handedness at T1. Although there was no significant difference in the proportion of participants in school between the two groups, the control group had achieved a significantly higher grade in school and had failed a grade significantly fewer times than did the FASD group. Furthermore, a significantly higher proportion of the FASD group had received special education (i.e. remedial teaching) at some point. On average, control participants had a significantly higher non-verbal IQ than FASD participants, and the mothers of control participants had significantly more years of education than those of FASD participants. In terms of home circumstances, FASD participants were significantly more likely to have been in foster care or adopted. None of the participants in either group had suffered a significant head injury or had visual or hearing impairments that would have interfered with their performance on neuropsychological testing.

Table 1

Sociodemographic and IQ Data for the Sample at T1 (N = 110)

Variable	Group						
	FASD	*n*	Control	*n*	*U*/χ^2/*t*	*p*	*r*/*V*/*d*
Age	14.7 (0.7)	48	14.5 (0.4)	62	1311.00[a]	.285	0.10
Handedness		48		62	4.20[b]	.122	0.20
Right	43 (89.6%)		61 (98.4%)				
Left	4 (8.3%)		1 (1.6%)				
Ambidextrous	1 (2.1%)		0 (0%)				
Sex		48		62	1.30[b]	.254	0.11
Male	30 (62.5%)		32 (51.6%)				
Female	18 (37.5%)		30 (48.4%)				
Maternal Education[†]	5.4 (2.5)	42[Δ]	7.9 (2.7)	61[Δ]	618.50[a]	< .001***	0.44
Leiter IQ	71.3 (9.5)	48	80.2 (10.8)	62	-4.55[c]	< .001***	0.87
In school		48		59[Δ]	-[d]	.586	0.07
Yes	46 (95.8%)		58 (93.5%)				
No	2 (4.2%)		1 (1.6%)				
Grade in School	7.5 (1.1)	46[Δ]	8.4 (1.0)	58[Δ]	641.00[a]	< .001***	0.47
Repeated a Grade		45[Δ]		58[Δ]	-[d]	< .001***	0.55
Yes	38 (79.2%)		17 (27.4%)				
No	7 (14.6%)		41 (66.1%)				
Special Education		41[Δ]		58[Δ]	4.67[b]	.031*	0.22
Yes	14 (34.1%)		9 (15.5%)				
No	27 (65.9%)		49 (84.5%)				
Foster Care/Adopted		48		59[Δ]	7.40[b]	.007**	0.26
Yes	11 (22.9%)		3 (5.1%)				
No	37 (77.1%)		56 (94.9%)				

Note. For all variables, means are presented with standard deviations in parentheses, except for Handedness, Sex, In School, Repeated a Grade, Special Education, Foster Care/Adopted, where counts are presented with proportions in parentheses.

[†] Maternal Education = Number of years of formal schooling completed by the participant's biological mother. [Δ] Demographic data was collected in a separate study. Some demographic data was not available, as the caregiver did not know or provide the required information.

[a] Mann-Whitney U test used. [b] Chi-square test used. [c] Independent sample *t*-test used. [d] Fischers Exact test used.

**p* < .05. ***p* < .01. ****p* < .001.

Substance exposure and diagnosis. Table 2 presents substance (alcohol and tobacco) exposure and diagnoses for the entire sample. All 48 FASD participants had greater than minimal alcohol exposure during pregnancy compared to none of the control participants. Six control participants (9.7%) had minimal alcohol exposure, defined as equal or less than one drink per week on average, and never more than two drinks on any occasion.

The majority (85.5%) of participants in the FASD group were diagnosed with FAS or partial FAS. Seven of the participants in the FASD group were assigned a diagnosis of 'not FAS' during the epidemiological study which identified the cohort from which the sample was recruited, but were nonetheless included in the FASD group given their history of more than minimal alcohol exposure during pregnancy. This was in line with the selection criteria of the multi-site study, in which the present study was embedded. All 62 participants in the control group had a diagnosis of 'not FAS'.

A significantly higher proportion of mothers of FASD participants smoked during pregnancy than mothers of control participants. None of the participants was exposed to any other substances *in utero*.

Table 2

Prenatal Substance Exposure and Diagnosis for the Sample at T1 (N = 110)

	Group						
Variable	FASD	*n*	Control	*n*	χ^2	*p*	*V*
Alcohol Exposure		48		62	110.00	<.001***	1.00
None	0 (0.0%)		56 (90.3%)				
Minimal[†]	0 (0.0%)		6 (9.7%)				
>Minimal	48 (100.0%)		0 (0.0%)				
Diagnosis		48		62	84.43	<.001***	0.88
Not FAS	7 (14.6%)		62 (100.0%)				
Partial FAS	9 (18.8%)		0 (0.0%)				
FAS	32 (66.7%)		0 (0.0%)				
Tobacco Use		46[Δ]		62	28.61	<.001***	0.52
Yes	38 (79.2%)		19 (30.6%)				
No	8 (16.7%)		43 (69.4%)				

Note. [†]Minimal Exposure: equal or less than one drink per week on average and never more than two drinks on any occasion during gestation.[Δ] Demographic data was collected in a separate study. Some demographic data was not available, as the caregiver did not know or provide the required information.

*$p < .05$ **$p < .01$ ***$p < .001$.

Sample Characteristics at T2

Demographic data. Children were reassessed approximately 18 months after T1 (M = 18.6 ± 1.9 months). A total of 33 FASD and 33 control participants were available for follow-up at T2. As in the case of T1, there were no significant between-group differences in terms of mean age at neuropsychological testing (FASD: M = 16.0 ± 0.5 years vs Control: M = 15.8 ± 0.4 years, U = 410.50, p = .085, r = 0.21), sex (FASD: 60.6% male and 39.4% female vs Control: 51.5% male and 48.5% female, χ^2 (1, N = 66) = 0.55, p = .457, V = 0.09) or handedness (FASD: 93.9% right and 6.1% left vs Control: 100% right, Fischer's, p = .492, V = 0.077). As in the case of T1, the FASD group had significantly lower non-verbal IQ than controls (FASD: M = 74.9 ± 7.9 vs Control: M = 81.4 ± 10.8, U = 341.00, p = .009, r = 0.32), and mothers of FASD participants had completed significantly fewer years education compared to mothers of control participants (FASD: M = 5.1 ± 2.5 years vs Control: M = 7.6 ± 2.4 years, U = 198.00, p < .001, r = 0.46).

Sample characteristics of those retained versus those lost to follow-up at T2. Children who were retained for follow-up at T2 did not differ significantly from those who were lost to follow-up in terms of maternal level of education, sex, or handedness in either the FASD (see Table 3) or the control group (see Table 4). Within the FASD group, those who were lost to follow-up had significantly lower IQ scores than those who were retained. This was most likely due to the sampling strategies of the larger study that this study is embedded in, which excluded participants with a WISC-IV IQ below 55. In both the FASD and control groups, participants who were lost to follow-up were significantly older than those who were retained. Although this result was statistically significant, from examining the mean ages in Table 3 and Table 4, it is unlikely to be of clinical significance because in both cases, the difference is less than six months.

Table 3

FASD Group: Sociodemographic Variables for those who were Retained versus those Lost to Follow-up at T2

Variable	Retained	*n*	Lost to follow-up	*n*	χ^2/t	*p*	*V/d*
Age	14.5 (0.5)	33	15.1 (0.7)	15	3.35	.002*	1.03
Handedness		33		15	-[a]	.240	0.25
Right	31 (93.9%)		12 (80.0%)				
Left	2 (6.1%)		2 (13.3%)				
Ambidextrous	0 (0.0%)		1 (6.7%)				
Sex		33		15	0.16	.688	0.06
Male	20 (60.6%)		10 (66.7%)				
Female	13 (39.4%)		5 (33.3%)				
Maternal Education[†]	5.1 (2.5)	28[Δ]	5.9 (2.3)	14[Δ]	1.07	.292	0.35
Leiter IQ	74.9 (7.9)	33	63.3 (7.7)		-4.80	<.001**	1.48

Note. For the variables age, Maternal Education and IQ, means are presented with standard deviations in parentheses. For the variables Handedness and Sex, actual numbers are presented with proportions in parentheses. [†] Maternal Education = Number of years of formal schooling completed by the child's biological mother. [Δ] Demographic data was collected in a separate study. Some demographic data was not available, as the caregiver did not know or provide the required information.

[a] Fisher's exact test performed.

*$p < .01$. **$p < .001$.

Table 4

Control Group: Sociodemographic Variables for those who were Retained versus those Lost to Follow-up at T2

Variable	Retained	*n*	Lost to follow-up	*n*	χ^2/t	*p*	*V/d*
Age	14.3 (0.4)	33	14.7 (0.4)	29	3.56	.001**	0.88
Handedness		33		29	-[a]	.468	0.14
Right	33 (100.0%)		28 (96.6%)				
Left	0 (0.0%)		1 (3.4%)				
Ambidextrous	0 (0.0%)		0 (0.0%)				
Sex		33		29	<.001	.987	.002
Male	17 (51.5%)		15 (51.7%)				
Female	16 (48.5%)		14 (48.3%)				
Maternal Education[†]	7.63 (2.38)	32[Δ]	8.1 (3.1)	29	0.73	.468	0.19
Leiter IQ	81.4 (10.8)	33	79.0 (10.8)	29	-0.87	.387	0.22

Note. For the variables age, Maternal education and IQ, means are presented with standard deviations in parentheses. For the variables Handedness and Sex, actual numbers are presented with proportions in parentheses. [†] Maternal Education = Number of years of formal schooling completed by the child's biological mother. [Δ] Demographic data was collected in a separate study. Some demographic data was not available, as the caregiver did not know or provide the required information.

[a] Fischer's Exact test performed.

*$p < .05$ **$p < .01$ ***$p < .001$.

The Executive Function Profile of Typically Developing Children from a Low SES Community

Testing Hypothesis 1.1

A series of one-sample *t*-tests was used to analyse the control group's performance at T1 in relation to the standard scores for the D-KEFS[2] and CANTAB[3] subtests. This was done to explore how typically developing South African children from a low-SES background perform on these neuropsychological tests. These results are presented in Table 5 and Table 6.

As shown in Table 5, the control group performed significantly worse than the published norms (i.e. scaled score mean of 10) on most of the D-KEFS subtests (all *p*s < .001, all *d*s > 0.46), except on Set Loss Errors for both the Verbal Fluency Test and Design Fluency Test, and Total Repeat Errors for the Design Fluency Test, where they performed significantly better (i.e. made fewer errors, all *p*s < .001, all *d*s > 0.65). There were no significant differences between the scaled scores obtained by the control group and normative data on the Switching condition of the Verbal Fluency Test, Total Errors on the Switching condition of the Trail Making Test, and the Move Accuracy Score of the Tower Test. On these three measures, the control group performed slightly worse on the Switching condition of the Verbal Fluency Test and the Move Accuracy Score of the Tower Test, but marginally

[2] Only those D-KEFS outcome measures for which scaled scores (as opposed to cumulative percentages) are provided in the manual were analysed.
[3] Only those subtests of the CANTAB that purport to measure executive functions and for which normative data (z-scores) were available was analysed. Big-Little Circle and Motor Screening are non-executive measures and were therefore excluded from this analysis. No normative data was available for SRT and CRT and these subtests were therefore excluded from this analysis.

better in terms of Total Errors on the Switching condition of the Trail Making Test. Clinically, their scores on all three latter measures fell within the expected (i.e. average) range.

Table 5

Comparing the Control Group's Performance on D-KEFS Subtests to Published Norms at T1 (n = 62)

D-KEFS Subtest	Min	Max	Mean	*SD*	*t, df = 61*	*p*	*d*
Verbal Fluency							
Letter Fluency (BAS)	1	12	6.5	3.0	-9.49	< .001**	1.20
Category Fluency	4	18	8.2	3.2	-4.58	< .001**	0.58
Switching	5	16	9.5	2.4	-1.78	.079	0.23
Set Loss Errors	1	13	11.7	2.5	5.11	< .001**	0.65
Repeat Errors	3	10	8.7	1.8	-5.89	< .001**	0.75
Trail Making Test							
Visual Scanning	1	12	6.1	3.2	-9.77	< .001**	1.24
Number Sequencing	1	11	6.2	2.9	-10.26	< .001**	1.30
Letter Sequencing	1	12	4.8	3.6	-11.42	< .001**	1.45
Number-Letter Switching	1	11	5.3	3.3	-11.07	< .001**	1.41
Motor Speed[a]	1	12	5.5	3.8	-9.15	< .001**	1.17
Switching Total Errors	1	12	10.0	2.5	0.10	.920	0.01
Design Fluency							
Filled Dots	3	13	7.3	2.0	-10.97	< .001**	1.39
Empty Dots	4	14	7.7	2.3	-8.12	< .001**	1.03
Switching	2	14	7.8	2.7	-6.46	< .001**	0.82
Set Loss Errors	6	14	11.5	2.2	5.56	< .001**	0.71
Repeat Errors	7	13	11.6	1.7	7.54	< .001**	0.96
Color-Word Interference							
Color Naming	1	12	6.4	3.0	-9.51	< .001**	1.21
Word Reading	1	14	7.90	3.4	-7.05	< .001**	0.89
Inhibition	1	13	7.7	2.7	-6.86	< .001**	0.87
Inhibition/Switching	1	13	7.7	3.2	-5.78	< .001**	0.73
Inhibition Total Errors	1	13	7.7	3.0	-6.13	< .001**	0.76
Switching Total Errors	1	13	7.9	3.3	-5.11	< .001**	0.75
Twenty Questions							
Total Questions Asked	1	14	5.4	4.7	-7.69	< .001**	0.98
Total Achievement Score	1	14	5.4	4.4	-8.10	< .001**	1.03
Tower Test							
Total Achievement Score	1	13	8.8	2.5	-3.59	.001*	0.46
Move Accuracy	1	18	9.5	3.2	-1.25	.215	0.16

Note. [a] Data based on 61 participants (one child did not complete the test).

*$p < .01$. **$p < .001$.

On the CANTAB (see Table 6), control participants performed significantly worse than the published norms on most tests (all *p*s ≤ .001, all *d*s > 0.06), except for the Pre-Ed Errors of the IED and Between and Within Errors on the SWM, where they performed significantly better (i.e. made fewer errors, all *p*s < .001, all *d*s > 0.16).

Descriptive statistics indicated that all data violated the assumption of normality. Given that there is no non-parametric test equivalent for one sample *t*-tests, and that it was inappropriate to transform the data as I was comparing against published norms, bootstrapping was performed on 10 000 samples to ensure that the results obtained were not spurious. A more stringent alpha level was used because of multiple comparisons; in this case, α = .01. The results of the bootstrapping were identical to those obtained from the one sample *t*-tests, indicating that the results on the D-KEFS and CANTAB were genuine effects.

Table 6

Comparing the Control Group's Performance on CANTAB Subtests to Publish Norms at T1 (n = 62)

	CANTAB Test	Min	Max	Mean	*SD*	*t, df = 61*	*p*	*d*
IED								
	Pre-Ed Errors	-3.6	0.7	0.3	0.7	-9.07	< .001**	0.38
	EDS Errors	-1.5	1.3	-0.3	0.8	-12.42	< .001**	0.39
	Total Errors Adjusted	-3.0	1.2	-0.0	0.7	-11.86	< .001*	0.06
SWM								
	Between Errors	-1.2	1.5	0.1	0.6	-11.42	< .001**	0.16
	Within Errors	-1.7	0.7	0.3	0.5	-10.27	< .001**	0.57
	Strategy	-2.0	2.4	-0.3	0.8	-11.99	< .001**	0.33

Note. IED = Intra-Extra Dimensional shift. SWM = Spatial Working Memory.

*p < .01. **p < .001.

Summary. This sample of typically developing children (i.e. the control group) performed significantly worse on nearly all tests of executive function compared to international norms. These results suggest that the Trail Making Test and Twenty Questions Test may be particularly sensitive to the impact of low socioeconomic status, as control participants' average scores fell more than one standard deviation below the mean. Although these tests were not excluded from the analysis at this stage, they were flagged as being potentially inappropriate for use as measures of executive function in the South African context.

Testing hypothesis 1.2

To determine which measures of executive function would be most useful in this sample, and to exclude measures where poorly developed non-executive abilities might impact the results, the performance of the FASD and control groups were compared on those tests that had non-executive measures. Raw scores, instead of scaled scores, were used as the D-KEFS and CANTAB are not normed for the South African population.

The data for the non-executive measures were not normally distributed, and the distributions between the two groups were not similar. Therefore, non-parametric tests were performed for all the analyses described below. The results for the relevant subtests of the D-KEFS are presented in Table 7. The FASD group performed significantly worse in terms of the time taken to complete the task on both the Visual Scanning and Letter Sequencing conditions of the Trail Making Test. There were no significant between-group differences in terms of the Number Sequencing or Motor Speed conditions, although Number Sequencing approached significance. An adequate performance on the primary executive measure of the

Trail Making Test, the Number-Letter Switching condition, requires intact visual scanning skills, basic numerical processing, letter sequencing, and motor speed. For the FASD group, a poor performance on the Number-Letter Switching condition may therefore indicate deficits in the non-executive abilities of visual scanning and letter sequencing rather than a deficit in the executive domain of cognitive flexibility. Therefore, this subtest of the D-KEFS was excluded from further analysis.

On the Color-Word Interference Test, the FASD group performed significantly worse than the control group in terms of time taken to complete the task on both the Color Naming and Word Reading conditions. Slow naming and reading speed may therefore account for the FASD group's slow performance on the Inhibition and Inhibition/Switching conditions. The Color-Word Interference Test of the D-KEFS was therefore excluded from further analysis.

There were no significant between-group differences on any of the non-executive CANTAB measures (see Table 8). These results indicate that participants in both groups could use the CANTAB touchscreen and follow the electronic instructions to complete the tests administered in this format. All CANTAB subtests were therefore retained for further analysis.

Table 7

Comparing the FASD and Control Group's Performance on Non-Executive Measures of the D-KEFS at T1 (N = 110)

	FASD *n* = 48			Control *n* = 62					
D-KEFS Tests	Mean	*SD*	Mean Rank	Mean	*SD*	Mean Rank	*U*	*p*	*r*
Trail Making Test									
Visual Scanning	37.0	9.6	65.2	32.3	9.4	48.0	1023.50	.005*	0.27
Number Sequencing	61.9	24.7	64.2	51.8	19.4	48.7	1069.00	.012	0.24
Letter Sequencing	85.8[a]	39.2	65.6	62.4	29.5	45.6	872.50	.001*	0.32
Motor Speed	65.0	32.2	59.3	57.7[c]	29.0	51.6	1259.00	.211	0.12
Color-Word Interference Test									
Color Naming	46.0	12.6	66.7	38.8	7.7	46.9	951.50	.001*	0.31
Word Reading	37.9[b]	15.1	65.4	30.3	9.1	46.4	925.50	.002*	0.30

Note. Raw scores were used to compare the performance of the FASD and control groups. [a] Data based on 45 participants. [b] Data based on 46 participants. [c] Data based on 61 participants.

*$p < .01$ (statistically significant for my chosen α level).

Table 8

Comparing the FASD and Control Group's Performance on Non-Executive Measures of the CANTAB at T1 (N = 110)

	FASD *n* = 48			Control *n* = 62					
CANTAB Tests	Mean	*SD*	Mean Rank	Mean	*SD*	Mean Rank	*U*	*p*	*r*
Motor Screening									
Mean Latency	1264.3	421.5	60.6	1157.6	298.9	51.5	1242.00	.138	0.14
Mean Error	8.0	2.3	59.3	7.7	2.6	52.6	1305.50	.266	0.11
Big-Little Circle									
Mean Correct Latency	972.7	188.2	56.0	984.0	222.7	55.1	1465.50	.892	0.01
Total Correct	40.0	0.2	54.2	40.0	0.0	56.5	1426.00	.106	0.15
Total Error	0.0	0.2	56.8	0.0	0.0	54.5	1426.00	.106	0.15

Note. Raw scores were used to compare the performance of the FASD and control groups.

As discussed above, various neuropsychological tests were excluded from further analysis based on a poor performance by the FASD compared to the control group on the non-executive component of these tests. However, a large number of variables remained (see Table 9 for descriptive statistics at T1). Therefore, a PCA using Varimax rotation was performed to exclude redundant variables and reduce the number of remaining variables into underlying domains of executive function.

Table 9

Raw Scores for all Neuropsychological Test Variables at T1 (N = 110)

	FASD (*n* = 48)				Control (*n* = 62)			
Neuropsychological Test	Min	Max	Mean	SD	Min	Max	Mean	SD
Verbal Fluency								
Letter Fluency	1	34	15.7	9.3	4	38	20.9	8.2
Category Fluency	11	50	26.7	7.4	20	55	30.5	7.9
Switching	5	15	10.6	2.3	8	17	11.5	2.1
Total Set Loss Errors	0	15	2.3	3.1	0	9	0.9	1.9
Total Repeat Errors	0	8	1.5	1.7	0	5	0.8	1.2
Design Fluency								
Filled Dots	1	10	5.0	2.0	1	13	6.2	2.3
Empty Dots	1	13	5.7	2.6	3	15	7.2	2.7
Switching	0	10	4.2	2.2	0	11	5.3	2.4
Total Set Loss Errors	0	14	3.5	3.5	0	8	2.5	2.2
Total Repeat Errors	0	12	3.6	3.7	0	13	3.2	3.4
Twenty Questions								
Initial Abstraction Score	4	37	6.5	6.9	4	46	13.1	11.6
Total Weighted Achievement Score	1	16	6.1	3.7	0	18	9.0	5.0
Total Repeat Questions	0	8	1.8	2.0	0	7	0.8	1.2
Total Set Loss Questions	0	4	0.3	0.8	0	2	0.2	0.6
Tower test								
Total Achievement Score	2	21	13.4	4.4	4	21	15.3	3.5
Total Rule Violations	0	28	3.9	4.5	0	21	1.9	3.3
IED								
Pre-ED Errors	3	25	8.4	4.4	4	40	7.9	5.5
EDS Errors	0	34	17.2	10.9	0	33	19.4	10.0
Total Errors Adjusted	9	142	44.4	24.7	9	140	46.9	22.0

Neuropsychological Test	FASD (n = 48)				Control (n = 62)			
	Min	Max	Mean	SD	Min	Max	Mean	SD
SWM								
Between Errors	4	76	51.9	15.6	9	72	41.4	14.9
Within Errors	0	15	2.5	2.9	0	13	2.0	3.0
Strategy	26	45	38.3	3.8	24	45	36.7	3.9
CRT								
Mean Latency	329	1114	571.4	172.4	319	778	504.2	114.2
Total Commission Errors	0	3	0.1	0.5	0	1	0.1	0.3
Total Omission Errors	0	1	0.1	0.3	0	1	0.0	0.1
SRT								
Mean Latency	250	971	514.7	164.7	230	794	448.7	131.0
Total Commission Errors	0	13	1.1	2.1	0	6	0.8	1.2
Total Omission Errors	0	1	0.0	0.2	0	1	0.0	0.2

Note. IED = Intra-Extra Dimensional shift. SWM = Spatial Working Memory. CRT = Choice Reaction Time. SRT = Simple Reaction Time.

Using only the data obtained from the control participants, I standardised all the variables (the test scores) into z-scores to make direct comparisons between tests that initially had different units of measurement. I reverse-scored some of the variables so that higher standardised scores represented better performance for all measures. These standardised scores were used in the PCA.

Variables were considered for inclusion in the PCA only if they correlated higher than 0.3 with any other variable. This resulted in 15 variables being included in the factor analysis (see Table 11). A PCA was conducted on the 15 variables with varimax rotation. The Kaiser-Meyer-Olkin was .585, indicating that the sampling was adequate to perform a factor analysis. In addition, Bartlett's test of sphericity, χ^2 (105) = 294.30, $p < .001$, indicated that the correlations among the variables were sufficient to perform a factor analysis. Five components had eigen values greater than one; however, an examination of the scree plot (see Figure 4) indicated that a four-factor solution would provide a better fit for the data. The combination of these four components explained 58.5% of the variance.

Table 10

Factor Loadings after Rotation for the Control Group at Time 1

Cognitive test	Factor 1	Factor 2	Factor 3	Factor 4
Letter Fluency	**.696**	-.118	-.131	.342
Category Fluency	**.530**	-.025	-.160	.452
Design Fluency Filled dots	**.791**	.124	.182	-.014
Design Fluency Empty dots	**.789**	.127	.179	-.219
Design Fluency Switching	**.613**	.138	.072	-.066
Tower Test	.340	**.406**	.207	.073
IED Total Errors Adjusted	-.065	**.746**	.048	.074
SRT Total Commission Errors	.155	**.780**	.054	-.194
SRT Total Omission errors	.158	**.722**	-.230	.312
Twenty Questions: Repeated Questions	.014	.371	**.485**	.132
SWM Between Errors	.164	-.056	**.863**	-.003
SWM Within Errors	-.102	-.093	**.617**	.101
SWM Strategy	.240	.112	**.686**	.038
CRT Mean Latency	.017	.090	.171	**.832**
SRT Mean Latency	-.064	.075	.130	**.830**

Note. IED = Intra-Extra Dimensional Set Shift. SRT = Simple Reaction Time. SWM = Spatial Working Memory. CRT = Choice Reaction Time

Figure 4

Scree Plot for PCA Based on Data for the Control Group at T1.

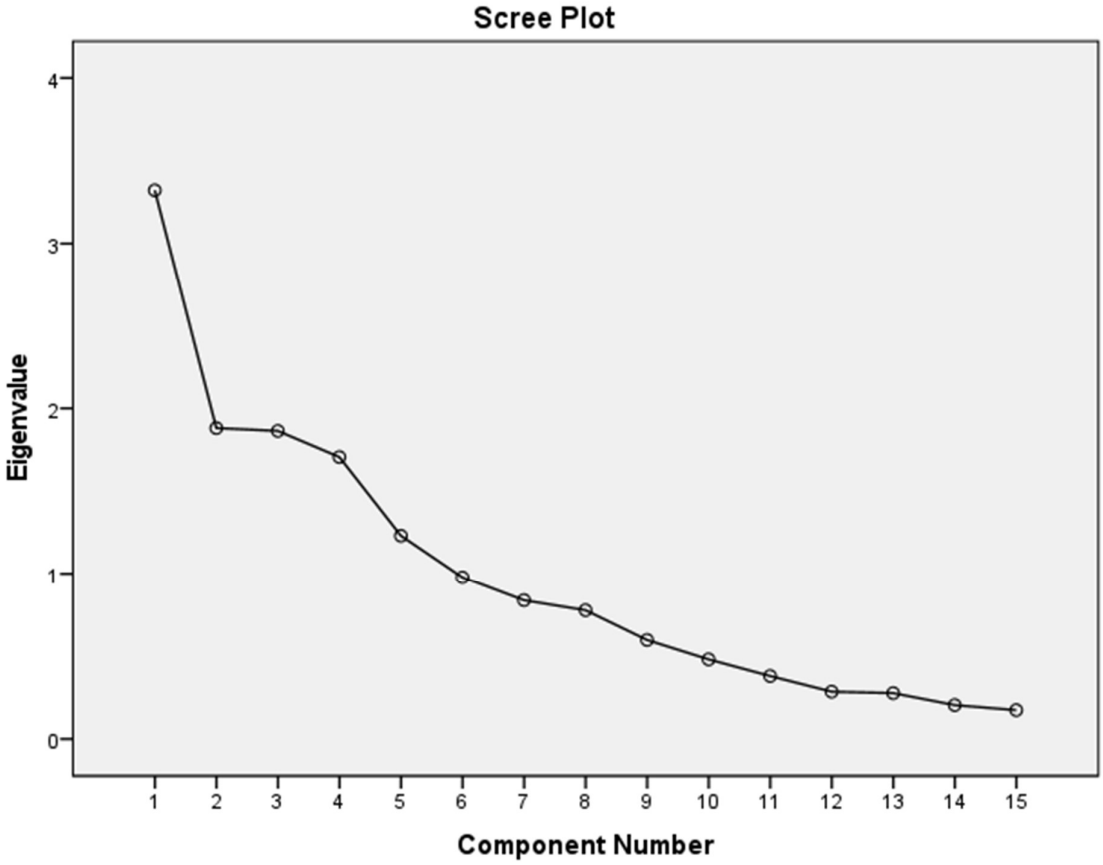


Table 10 lists the factor loadings after rotation. Examining the variables that loaded on the same components indicated that tests that are generally considered to measure generativity and fluency loaded on Factor 1. This factor was therefore named *Generativity*. Tests that generally measure selective attention and the ability to inhibit prepotent responses and prevent errors loaded on Factor 2. Therefore, this factor was named *Attentional Control*. Tests that generally measure the ability to hold information in mind and manipulate it loaded on Factor 3. Therefore, this factor was named *Working Memory*. Finally, tests that generally measure speed of response loaded on Factor 4. This factor was therefore named *Processing Speed.*

Summary. This sample of typically developing children (the control group) performed poorly on the non-executive conditions of both the Trail Making Test and Color-Word Interference Test of the D-KEFS. As poor non-executive abilities are highly likely to negatively impact on participants' performance on the primary executive measures of these tests, the Trail Making Test and Color-Word Interference Test were excluded from further analysis.

A PCA using Varimax rotation was then performed to exclude redundant variables and reduce the number of remaining variables into underlying domains of executive function. Variables were only considered for inclusion in the PCA if they correlated higher than 0.3 with any other variable. This resulted in 15 variables being entered into the PCA. A four-factor solution explaining 58.5% of the variance was found to be the best fit for the data. Examining variables that loaded on the same components, these factors/domains were named *Generativity*, *Attentional Control*, *Working Memory,* and *Processing Speed*.

Group Differences and Development: Neuropsychological Measures

Testing Hypotheses 2.1, 2.2, and 2.3

Composite variables were calculated for both the FASD and control groups at T1 and T2 by averaging the z-scores for those variables that loaded on each factor (see Table 11). A repeated-measures factorial ANCOVA was performed using time (T1, T2) and group (FASD, Control) as independent variables and composite executive function scores (*Generativity*, *Attentional Control*, *Working Memory,* and *Processing Speed*) as dependent variables. Nonverbal IQ (as measured by the Lieter-R) and Maternal Education were used as covariates.

Table 11

Descriptive Statistics for Composite z-scores obtained by the FASD and Control Group on the Four Executive Function Domains at T1 and T2

	FASD *n* = 33						Control *n* = 33					
	Time 1			Time 2			Time 1			Time 2		
Composite Variable	M	SD	95% CI	M	SD	95% CI	M	SD	95% CI	M	SD	95% CI
Generativity	-0.39	0.61	-0.71 – (-0.08)	-0.34	0.74	-0.68 – (-0.006)	0.01	0.75	-0.34 – 0.33	<0.01	0.72	-0.34 – 0.34
Attentional Control	-0.06	0.70	-0.34 – 0.22	-0.14	0.58	-0.41 – 0.12	0.03	0.47	-0.25 – 0.30	<0.01	0.57	-0.26 – 0.27
Working Memory	-0.53	0.76	-0.88 – (-0.19)	-0.35	0.68	-0.65 – (-0.05)	0.02	0.73	-0.33 – 0.36	0[a]	0.61	-0.30 – 0.30
Processing Speed	-0.43	1.33	-0.96 – 0.10	-0.56	1.78	-1.22 – 0.10	0.05	0.92	-0.48 – 0.58	<0.01	0.92	-0.66 – 0.66

Note. [a] Exact data value was -0.005.

Although the distributions for several composite variables deviated slightly from the normal distribution, this was not consistently the case at both T1 and T2. Transforming the data (via logging, exponential, and inversion) did not improve the distribution. Therefore, it was decided that the original data format would be retained, given that ANCOVA is robust to violations of normality when other assumptions are upheld.

Table 12 shows the adjusted mean composite scores for both groups. The covariate Non-verbal IQ was a significant predictor of *Generativity*, $F(1, 56) = 10.10$, $p = .002$, $\eta^2 = .15$, but the covariate Maternal Education was not, $F(1, 56) = 2.67$, $p = 108$, $\eta^2 = .05$. After controlling for the covariate Non-verbal IQ, there was no significant main effect of Time, $F(1, 63) = 0.34$, $p = .560$, $\eta^2 < .01$, or Group, $F(1, 63) = 0.91$, $p = .180$, $\eta^2 = .03$, nor a significant Time*Group interaction, $F(1, 63) = 0.46$, $p = .831$, $\eta^2 < .01$.

Similar results were obtained for *Attentional Control*, with the covariate Non-verbal IQ also being a significant predictor, $F(1,56) = 11.04$, $p = .002$, $\eta^2 = .17$, while the covariate Maternal Education was not, $F(1,56) < 0.01$, $p = .950$, $\eta^2 <.01$. After controlling for the covariate Non-verbal IQ, there was no significant main effect of Time, $F(1, 63) = 0.31$, $p = .579$, $\eta^2 < .01$, or Group, $F(1,63) = 0.02$, $p = .961$, $\eta^2 < .01$, nor a significant Time*Group interaction, $F(1, 63) = 0.25$, $p = .616$, $\eta^2 < .01$.

For *Working Memory*, neither the covariate Non-verbal IQ, $F(1,56) = 4.62$, $p = .036$, $\eta^2 = .08$, nor Maternal Education $F(1,56) = 3.21$, $p = .079$, $\eta^2 = .05$, were significant predictors of performance on this variable. There was no significant main effect of Time, $F(1,64) = 0.98$, $p = .327$, $\eta^2 = .02$, nor a significant Time*Group interaction, $F(1,64) = 1.44$, $p = .235$, $\eta^2 = .02$. However, there was a significant main effect of Group, $F(1,64) = 9.05$, $p = .004$, $\eta^2 = .12$, with FASD participants performing significantly worse.

For *Processing Speed*, the covariate Non-verbal IQ was a significant predictor, $F(1, 56) = 7.76$, $p = .007$, $\eta^2 = .12$, while the covariate Maternal Education was not $F(1, 56) = 3.19$, $p = .080$, $\eta^2 = .05$. After controlling for the covariate Non-verbal IQ, there was no significant main effect of Time, $F(1, 63) = 0.04$, $p = .853$, $\eta^2 < .01$, or Group, $F(1,63) = 091$, $p = .344$, $\eta^2 = .01$, nor a significant Time*Group interaction, $F(1, 63) = 0.43$, $p = .837$, $\eta^2 < .01$.

Summary. The above analyses suggest that nonverbal IQ has an important impact on performance on measures of executive function across both groups. The performance of the FASD and control groups did not differ significantly on the executive function domains *Generativity*, *Attentional Control* or *Processing Speed* after controlling for non-verbal IQ. *Working Memory* was not influenced by non-verbal IQ, and FASD participants performed significantly worse than controls. There was no time effect for any of the executive function domains (i.e. no developmental change over the 18-month period).

Table 12

Composite z-scores for the Four Executive Function Domains Adjusted for the Covariate Non-verbal IQ: FASD and Control Group at Both T1 and T2

	FASD *n* = 33						Control *n* = 33					
	Time 1			Time 2			Time 1			Time 2		
Composite Variable	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI	M	SE	95% CI
Generativity	-0.31	0.11	-0.53 – (-0.08)	-0.27	0.13	-0.52 – (-0.02)	-0.08	0.11	-0.31 – 0.15	-0.08	0.13	-0.33 – 0.18
Attentional Control	0.01	0.10	-0.20 – 0.21	-0.09	0.10	-0.29 – 0.11	-0.04	0.10	-0.25 – 0.16	-0.05	0.10	-0.25 – 0.15
Working Memory	-0.53	0.76	-0.88 – (-0.19)	-0.35	0.68	-0.65 – (-0.05)	0.02	0.73	-0.33 – 0.36	0[a]	0.61	-0.30 – 0.30
Processing Speed	-0.30	0.20	-0.69 – 0.09	-0.43	0.25	-0.92 – 0.06	-0.07	0.20	-0.46 – 0.32	-0.13	0.25	-0.62 – 0.36

Note. [a] Exact data value was -0.005.

Group Differences: Behaviour Rating Scales

As discussed in Chapter 4 (Methods), behavioural data obtained from the BRIEF Teacher and Parent questionnaires was analysed only at T1.

Comparing the FASD and the Control Group Using BRIEF International Normative Data

To allow for comparison with previous studies in the field, *t*-scores were computed for each of the eight clinical scales, the three index scores: The Metacognition Index (MI) and Behavioral Regulation Index (BRI), and the Global Executive Composite (GEC) of the BRIEF Teacher and BRIEF Parent using international normative data. The frequency with which participants in the FASD and control groups had scores in the clinically impaired range (defined as *a t* score ≥ 65) was compared using a series of Chi-square analyses.

Testing Hypothesis 3.1

BRIEF Teacher. Table 13 presents the proportion of participants in both the FASD and control groups who obtained scores in the clinically impaired range compared to international normative data (i.e. *t* scores ≥ 65) on the BRIEF Teacher. For the FASD group, the percentage impaired on the clinical scales ranged from a low of 41.7% for both Inhibit and Emotional Control to a high of 85.4% for Plan/Organize. A similar pattern was observed for the control group, with the percentage impaired being the lowest for Inhibit and Emotional Control (26.2%), and the highest for Plan/Organize (54.1%).

Chi-square analyses revealed that the severity of executive dysfunction as rated by teachers differed significantly between the FASD and control groups on the Working Memory, Plan/Organize, Organization of Materials, and Monitor clinical scales. In all cases, a significantly higher proportion of FASD participants were classified as having scores in the

clinically impaired range than controls. On the two index scores, a significantly higher proportion of FASD participants had scores in the clinically impaired range on the MI. Although the BRI was significant at the conventional level, it was not significant at my more stringent level. There was a significant between-group difference on the overall GEC score, with a substantially higher proportion of participants in the FASD group obtaining scores in the impaired range.

Table 13

Chi-square Analysis of the BRIEF Teacher: Proportion of Children from both the FASD and Control Group who Scored in the Impaired Range

Index/scale	FASD $n = 48$	Control $n = 61$	χ^2	p	V
Inhibit	20 (41.7%)	16 (26.2%)	2.89	.089	.16
Shift[a]	34 (72.3%)	31 (50.8%)	5.13	.024*	.22
Emotional Control	20 (41.7%)	16 (26.2%)	2.89	.089	.16
Initiate	35 (72.9%)	29 (47.5%)	7.14	.008**	.26
Working Memory	37 (77.1%)	31 (50.8%)	7.90	.005**	.27
Plan/Organize	41 (85.4%)	33 (54.1%)	12.09	.001**	.33
Organization of Materials	26 (54.2%)	14 (23.0%)	11.27	.001**	.32
Monitor	35 (72.9%)	28 (45.9%)	8.04	.005**	.27
BRI[a]	28 (59.6%)	24 (39.3%)	4.35	.037*	.20
MI	41 (85.4%)	30 (49.2%)	15.53	<.001***	.38
GEC[a]	38 (80.9%)	32 (52.5%)	9.38	.002**	.30

Note. Counts are presented, with proportions in parentheses. The cut-off for impairment is $t \geq 65$. BRI = Behavioral Regulation Index. MI = Metacognition Index. GEC = Global Executive Composite. [a] FASD group $n = 47$ due to missing data.

*$p < .05$. **$p < .01$. ***$p < .001$.

BRIEF Parent. Table 14 presents the proportion of participants in both the FASD and control groups who obtained scores in the impaired range compared to international normative data ($t \geq 65$) on the BRIEF Parent. For the FASD group, the percentage impaired on the clinical scales ranged from a low of 22.9% for both Initiate and Organization of

Materials to a high of 62.5% for Working Memory. For the control group, the percentage impaired on the clinical scales ranged from 8.6% on both Emotional Control and Organization of Materials, to a high of 17.2% for both Shift and Working Memory.

Chi-square analyses revealed that the severity of executive dysfunction, as rated by parents, differed significantly between the FASD and control groups on the Inhibit, Emotional Control, Working Memory, Plan/Organize, and Monitor clinical scales. In all cases, a significantly higher proportion of FASD participants were classified as having scores in the clinically impaired range compared to controls. A significantly higher proportion of participants in the FASD group were classified as having scores in the clinically impaired range as measured by the MI and BRI. There was also a significant between-group difference on the overall GEC score, with a substantially higher proportion of participants in the FASD group obtaining scores in the impaired range.

Table 14

Chi-square Analysis of the BRIEF Parent: Proportion of Participants from Both the FASD and Control Group who Scored in the Impaired Range

Index/scale	FASD $n = 48$	Control[a] $n = 58$	χ^2	p	V
Inhibit	15 (31.3%)	6 (10.3%)	7.23	.007**	.26
Shift	17 (35.4%)	10 (17.2%)	4.57	.033*	.21
Emotional Control	18 (37.5%)	5 (8.6%)	12.89	<.001***	.35
Initiate	11 (22.9%)	9 (15.5%)	0.94	.332	.09
Working Memory	30 (62.5%)	10 (17.2%)	22.90	<.001***	.47
Plan/Organize	23 (47.9%)	8 (13.8%)	14.78	<.001***	.37
Organization of Materials	11 (22.9%)	5 (8.6%)	4.19	.041*	.20
Monitor	18 (37.5%)	6 (10.3%)	11.06	.001**	.32
BRI	20 (41.7%)	6 (10.3%)	13.92	<.001***	.36
MI	21 (43.8%)	6 (10.3%)	15.44	<.001***	.38
GEC	23 (47.9%)	5 (8.6%)	20.87	<.001***	.44

Note. Counts are presented, with proportions in parentheses. The cut-off for impairment is $t \geq 65$. BRI = Behavioral Regulation Index. MI = Metacognition Index. GEC = Global Executive Composite. [a] Control group $n = 58$ due to missing data.

*$p < .05$ **$p < .01$ ***$p < .001$.

Comparing the FASD and the Control Group Using BRIEF Raw Scores

Since the BRIEF is not normed for the South African population, the use of standardised scores might obscure potential differences between the FASD and control groups. Raw scores were therefore used to compare the two groups in all subsequent analyses. Separate one-way ANCOVAs were performed using group (FASD, Control) as independent variables and raw scores for each of the eight clinical scales and the GEC score of the BRIEF Teacher and BRIEF Parent as dependent variables. Nonverbal IQ (as measured by the Leiter-R) and Maternal Education were used as covariates.

Table 15 presents descriptive statistics for raw scores obtained by the FASD and control groups on the eight clinical scales and the GEC score of the BRIEF Teacher, while Table 16 presents descriptive statistics for the same scales on the BRIEF Parent.

Table 15

Descriptive Statistics for BRIEF Teacher Raw Scores for the FASD and Control Group at T1

	FASD (*n* =48)					Control (*n* = 61)				
Index/scale	Min	Max	Mean	SD	95% CI	Min	Max	Mean	SD	95% CI
Inhibit	10	28	16.1	5.0	14.7 – 17.6	10	25	14.3	4.4	13.1 – 15.4
Shift	10	26	17.6[a]	4.3	16.4 – 18.9	10	23	15.1	4.2	14.0 – 16.2
Emotional Control	9	26	13.9	4.4	12.7 – 15.2	9	20	12.0	3.3	11.1 – 12.8
Initiate	7	21	15.1	3.8	14.0-16.2	7	21	12.2	3.6	11.4 – 13.2
Working Memory	10	29	20.7	5.1	19.2 – 22.2	10	26	16.9	4.6	15.7 – 18.0
Plan/Organize	10	29	21.7	5.0	20.2 – 23.1	10	29	17.5	5.1	16.2 – 18.8
Organization of Materials	7	16	10.7	2.9	9.8 – 11.5	7	15	8.7	2.4	8.1 – 9.3
Monitoring	10	30	20.0	5.2	18.5 – 21.5	10	27	16.5	4.6	15.3 – 17.7
GEC	73	190	135.5[a]	29.2	126.9 – 144.0	73	165	113.0	28.1	105.8 – 120.2

Note. [a] Data based on 47 participants in the FASD group (one participant's teacher did not answer all the questions included in the Shift scale, therefore, a total score for the Shift scale and GEC could not be calculated for that participant). GEC = Global Executive Composite.

Table 16

Descriptive Statistics for BRIEF Parent Raw Scores for the FASD and Control Group at T1

	FASD (*n* = 48)					Control (*n* = 58)				
Index/scale	Min	Max	Mean	SD	95% CI	Min	Max	Mean	SD	95% CI
Inhibit	10	29	16.5	5.1	15.1 – 17.9	10	30	13.5	4.7	12.2 – 14.7
Shift	8	24	14.1	4.0	13.0 – 15.2	8	24	11.9	3.5	10.9 – 12.9
Emotional Control	10	26	17.6	4.9	16.2 – 18.9	10	28	15.0	4.4	13.8 – 16.2
Initiate	9	23	14.8	3.4	13.7 – 15.8	8	24	12.4	3.8	11.5 – 13.4
Working Memory	11	30	20.4	5.4	18.9 - 21.9	10	29	15.3	5.0	14.0 – 16.7
Plan/Organize	12	36	24.1	6.5	22.2 – 26.0	12	36	18.2	5.9	16.7 – 19.8
Organization of Materials	6	18	11.8	4.0	10.7 – 12.8	6	18	9.6	3.6	8.6 – 10.6
Monitoring	8	24	15.4	4.2	14.2 – 16.7	8	23	11.9	3.7	10.9 – 12.9
GEC	79	199	134.5	31.9	125.3 – 143.8	72	211	107.9	29.9	100.0 – 115.7

GEC = Global Executive Composite.

Testing Hypothesis 3.2

The ANCOVA results for the BRIEF Teacher are summarised in Table 17. The covariate Maternal Education was not a significant predictor of scores on any of the clinical scales or the GEC. Non-verbal IQ was a significant predictor of the Inhibit, Shift, Initiate, Working Memory, Plan/Organize, Monitor scales, and the GEC. Adjusted means for these scores are reported in Table 18. After controlling for Non-verbal IQ, no between-group differences were found for any of these clinical scales or the GEC. Emotional Control and Organization of Materials did not have any significant covariates, and in both cases, teachers rated the FASD group as displaying significantly more difficulties with executive function than the control group.

Table 17

ANCOVA/ANOVA Results for BRIEF Teacher at T1

Main effect of Group	SS	*df*	*F*	*p*	η^2
Inhibit					
Covariate Non-verbal IQ	154.80	1,101	7.96	.006**	0.08
Covariate Maternal Education	5.96	1,101	0.31	.581	< 0.01
Main effect of Group	12.09	1,107	0.58	.450	0.01
Shift					
Covariate Non-verbal IQ	236.36	1,100	15.35	< .001**	0.14
Covariate Maternal Education	31.53	1,100	2.05	.156	0.02
Main effect of Group	28.94	1,107	1.79	.184	0.02
Emotional Control					
Covariate Non-verbal IQ	75.71	1,101	5.44	.022*	0.05
Covariate Maternal Education	0.38	1,101	0.03	.868	< 0.01
Main effect of Group	106.02	1, 108	7.81	.009**	0.13
Initiate					
Covariate Non-verbal IQ	334.88	1,101	33.91	< .001**	0.26
Covariate Maternal Education	23.40	1,101	2.37	.127	0.02
Main effect of Group	26.87	1, 107	2.50	.117	0.02
Working Memory					
Covariate Non-verbal IQ	458.12	1,101	26.91	< .001**	0.22
Covariate Maternal Education	90.72	1,101	5.33	.023*	0.05
Main effect of Group	77.28	1,107	4,10	.045*	0.04
Plan/Organize					
Covariate Non-verbal IQ	490.57	1,101	26.60	< .001**	0.21
Covariate Maternal Education	127.89	1,101	6.93	.010*	0.07
Main effect of Group	103.87	1,107	4.97	.028*	.05
Organization of Materials					
Covariate Non-verbal IQ	10.44	1,101	1.62	.206	0.02
Covariate Maternal Education	10.06	1,101	1.56	.215	0.02
Main effect of Group	106.39	1,108	15.54	<.001**	0.13
Monitor					
Covariate Non-verbal IQ	413.64	1,101	22.23	< .001**	0.19
Covariate Maternal Education	24.42	1,101	1.31	.255	0.01
Main effect of Group	57.53	1, 107	2.85	.094	.026
GEC					
Covariate Non-verbal IQ	15247.40	1,101	24.36	<.001	.201
Covariate Maternal Education	1656.29	1,101	2.65	.107	.027
Main effect of Group	2663.93	1,107	3.94	.050	.036

Note. For the variables Inhibit, Shift, Initiate, Working Memory, Plan/Organize, and Monitor, the main effect of group is reported after controlling for the covariate Non-verbal IQ. For the variables Emotional Control and Organization of Materials, no covariates were significant predictors; therefore, an ANOVA was performed, and the main effect of group was reported. Maternal Education = Maternal Level of Education. GEC = Global Executive Composite.

Table **18**

BRIEF Teacher Adjusted Means

	FASD			Control		
Index/scale	M	SE	95% CI	M	SE	95% CI
Inhibit	15.5	0.7	14.1 – 16.9	14.7	0.6	13.5 – 16.0
Shift	16.9	0.6	15.6 – 18.1	15.7	0.5	14.6 – 16.8
Initiate	14.1	0.1	13.1 – 15.1	13.0	0.4	12.1 – 13.9
Working Memory	19.6	0.7	17.9 – 21.3	17.7	0.6	16.2 – 19.3
Plan/Organize	20.5	0.7	18.7 – 22.4	18.4	0.6	16.7 – 20.0
Monitor	18.9	0.7	17.6 – 20.3	17.3	0.6	16.1 – 18.5
GEC	129.0	4.0	121.1 – 137.0	118.0	3.5	111.1 – 124.9

Note. Emotional Control and Organization of Materials are not included in this table as neither of the covariates significantly predicted this domain. GEC = Global Executive Composite.

Testing Hypothesis 3.3

The ANCOVA results for the BRIEF Parent are summarised in Table 19. The covariate Maternal Education was not a significant predictor of scores on any of the BRIEF Parent clinical scales or the GEC. Non-verbal IQ was only a significant predictor for the clinical scale Monitor. The adjusted mean for this scale is reported in Table 20. After controlling for any significant covariates, no between-group differences were found for any of the clinical scales, except for Plan/Organize, Monitor, and the GEC. In all cases, parents rated the FASD group as displaying significantly more difficulties with executive function than the control group.

Table 19

ANOVA/ANCOVA Results for BRIEF Parent at T1

Main Effect of Group	SS	*df*	*F*	*p*	η^2
Inhibit					
Covariate Non-verbal IQ	79.59	1,98	3.53	.063	0.04
Covariate Maternal Education	48.26	1,98	2.14	.147	0.02
Main effect of Group	15.13	1,98	0.67	.415	<0.01
Shift					
Covariate Non-verbal IQ	30.66	1,98	2.26	.136	0.02
Covariate Maternal Education	0.004	1,98	0.000	.987	<0.01
Main effect of Group	30.25	1,98	2.23	.138	0.02
Emotional Control					
Covariate Non-verbal IQ	59.53	1,98	2.74	.101	0.03
Covariate Maternal Education	24.19	1,98	1.11	.294	0.01
Main effect of Group	14.58	1,98	0.67	.414	<0.01
Initiate					
Covariate Non-verbal IQ	3.05	1,98	0.24	.625	<0.01
Covariate Maternal Education	2.51	1,98	0.20	.658	<0.01
Main effect of Group	47.04	1,98	3.69	.058	0.04
Working Memory					
Covariate Non-verbal IQ	74.79	1,98	2.99	.087	0.03
Covariate Maternal Education	17.95	1,98	0.72	.399	<0.01
Main effect of Group	163.65	1,98	6.55	.012*	0.07
Plan/Organize					
Covariate Non-verbal IQ	224.88	1,98	6.24	.014*	0.06
Covariate Maternal Education	20.98	1,98	0.58	.448	<0.01
Main effect of Group	896.35	1,105	23.44	<.001**	0.18
Organization of Materials					
Covariate Non-verbal IQ	0.72	1,98	0.05	.819	<0.01
Covariate Maternal Education	9.33	1,98	0.68	.411	<0.01
Main effect of Group	62.13	1,98	4.45	.036*	0.05
Monitor					
Covariate Non-verbal IQ	102.63	1,98	7.20	.009**	0.07
Covariate Maternal Education	11.47	1,98	0.81	.372	<0.01
Main effect of Group	146.42	1,105	10.12	.002**	.09
GEC					
Covariate Non-verbal IQ	3231.41	1,98	3.56	.062	.036
Covariate Maternal Education	513.57	1,98	0.57	.453	.006
Main effect of Group	18641.53	1,105	19.62	<.001	.159

Note: For the variable Monitor, the main effect of group is reported after controlling for the covariate Non-verbal IQ. For all the other BRIEF Parent variables, no covariates were significant predictors, therefore an ANOVA was run, and the main effect of group reported. Maternal Education = Maternal Level of Education. GEC = Global Executive Composite.

Table 20

BRIEF Parent Adjusted Means

	FASD			Control		
Index/scale	M	SE	95% CI	M	SE	95% CI
Monitor	14.9	0.6	13.8 – 16.1	12.3	0.5	11.3 – 13.4

Summary. When compared against international norms, a significantly higher proportion of the FASD group versus controls were classified as having scores in the clinically impaired range on five of the clinical scales, the MI, and the GEC of the BRIEF Teacher. For the BRIEF Parent, a significantly higher proportion of the FASD group versus controls had scores in the clinically impaired range on five of the clinical scales, the BRI, the MI, and the GEC. Significant results were found for the clinical scales Working Memory, Plan/Organize and Monitor on both the BRIEF Teacher and BRIEF Parent.

Using raw scores, significant differences were found between the FASD and control groups on the clinical scales Emotional Control and Organization of Materials of the BRIEF Teacher. On the BRIEF Parent, significant differences were found for Plan/Organize, Monitor, and the GEC. Incidentally, it was found that the covariate Maternal Education was not a significant predictor of the extent of executive difficulties on either the BRIEF Teacher or the BRIEF Parent. However, non-verbal IQ was a significant predictor of executive difficulties on six of the clinical scales and the GEC of the BRIEF Teacher, and only one of the clinical scales of the BRIEF Parent.

Relationship between Neuropsychological Measures of Executive Function and the BRIEF

To investigate the relationship between participants' performance on neuropsychological measures of executive function and the extent of executive difficulties

they display in their daily lives as rated by parents and teachers on the BRIEF, a series of correlations and regressions were performed.

Testing Hypothesis 4.1

Teacher Ratings for the FASD Group. In general, the pattern of correlations in Table 21 shows that for the FASD group, a better performance on the composite cognitive domains *Attentional Control*, *Generativity*, and *Processing Speed* were associated with fewer executive difficulties in daily life. The cognitive composite *Attentional Control* was significantly negatively correlated with the BRIEF Teacher (a) Emotional Control ($p < .001$), and (b) Monitor ($p = .009$) clinical scales. The cognitive composite *Generativity* was significantly negatively correlated with the BRIEF Teacher (a) Initiate ($p < .001$), (b) Working Memory ($p < .001$), (c) Plan/Organize ($p = .001$), (d) Organization of Materials ($p = .002$), and (e) Monitor ($p < .001$) clinical scales. The cognitive composites *Processing Speed* and *Working Memory* were not significantly correlated with any of the BRIEF Teacher clinical scales. However, in general, for the composite cognitive domain *Working Memory*, a better performance was associated with more severe executive difficulties in daily life (as rated by teachers).

Table 21

FASD Group: Correlations Between Composite Cognitive Scores and BRIEF Teacher Raw Scores

Composite Cognitive Score / BRIEF Teacher Raw Score	Attentional Control	Generativity	Working Memory	Processing Speed
Inhibit	-.206	-.277	.069	-.133
Shift	-.221	-.335	.175	.010
Emotional Control	-.463**	-.147	.048	-.187
Initiate	-.272	-.483**	-.201	-.059
Working Memory	-.257	-.507**	-.085	-.060
Plan/Organize	-.251	-.446*	.009	-.017
Organization of Materials	.043	-.404*	.069	.038
Monitor	-.341*	-.462**	.107	-.080

Note. Data presented are Pearson *r* correlation coefficients.

*$p < .01$. **$p < .001$.

For the FASD group on the BRIEF Teacher, none of the composite cognitive scores were significant predictors of Inhibit and Shift. For Emotional Control, the composite cognitive score *Attentional Control* was a significant predictor, explaining 22% of the variance in this variable (see Table 22). Looking at the B coefficient, higher *Attentional Control* scores predicted better Emotional Control as rated by teachers (see Table 23). For Initiate, the composite cognitive score *Generativity* was a significant predictor explaining 23% of the variance in this variable. Looking at the B coefficient, higher *Generativity* scores predict a better ability to initiate. The composite cognitive scores *Processing Speed* and *Generativity* were significant predictors and explained 30%, 25%, and 24% of the variance in the variables Working Memory, Plan/Organize, and Organization of Materials, respectively. However, upon further analysis, *Generativity* emerged as the only significant predictor of these measures. Looking at the B coefficients, higher *Generativity* scores predicted better Working Memory, Plan/Organize, and Organization of Materials scores, as rated by teachers. Lastly, for Monitor, although the overall model containing the composite cognitive scores

Working Memory, *Attentional Control* and *Generativity* were significant predictors, explaining 32% of the variance in this variable, only *Generativity* was a significant predictor. Looking at the B coefficient, higher *Generativity* scores predicted better Monitor scores, as rated by teachers.

Table 22

ANOVA Summary Table for Regression Models: FASD Group, BRIEF Teacher

BRIEF Teacher measure	SS	df	MS	*F*	*p*	R^2
Inhibit						
Model: All cognitive composites	138.91	4, 47	34.73	1.41	.246	.116
Shift						
Model: All cognitive composites	203.01	4, 46	50.78	3.24	.021	.236
Emotional Control						
Model: Attentional Control	195.88	1,47	195.88	12.57	.001**	.215
Initiate						
Model: Generativity	159.00	1,47	159.00	13.99	.001**	.233
Working Memory						
Model: Processing Speed & Generativity	367.64	2,47	183.82	9.75	<.001***	.302
Plan/Organize						
Model: Processing Speed & Generativity	298.96	2,47	149.48	7.52	.002**	.251
Organization of Materials						
Model: Processing Speed & Generativity	93.64	2,47	46.82	6.90	.002**	.235
Monitor						
Model: Working Memory, Attentional Control & Generativity	402.94	3,47	134.31	6.74	.001**	.315

Table 23

Coefficients in Significant Regression Models: FASD, BRIEF Teacher

Final Model	B	SE	*β*	*t*	*p*
Emotional Control					
Constant	13.43	0.59	-	22.87	<.001
Attentional Control	-2.82	0.80	-0.46	-3.55	.001
Initiate					
Constant	13.67	0.62	-	22.18	<.001
Generativity	-2.66	0.71	-0.48	-3.74	.001
Working Memory					
Constant	18.81	0.80	-	23.65	<.001
Generativity	-4.59	1.05	-0.63	-4.39	<.001
Processing Speed	0.99	0.58	0.24	1.71	.094
Plan/Organize					
Constant	20.00	0.82	-	24.51	<.001
Generativity	-4.17	1.07	-0.57	-3.88	<.001
Processing Speed	1.05	0.60	0.26	1.77	.084
Organization of Materials					
Constant	9.80	0.48	-	20.54	<.001
Generativity	-2.33	0.63	-0.55	-3.70	.001
Processing Speed	0.71	0.35	0.31	2.05	.046
Monitor					
Constant	18.96	0.92	-	20.65	<.001
Attentional Control	-1.96	0.97	-0.27	-2.02	.049
Generativity	-3.18	0.99	-0.42	-3.19	.003
Working Memory	1.87	0.96	0.25	1.95	.058

Teacher Ratings for the Control Group. In general, the pattern of correlations in Table 24 shows that, for the control group, better performance on all four composite cognitive domains was associated with lower ratings of executive difficulties in daily life by teachers. The cognitive composite *Attentional Control* was significantly negatively correlated with the BRIEF Teacher (a) Inhibit and Emotional Control (both *p's* < .001), and (b) Shift, Initiate, Working Memory, Plan/Organize, and Monitor (all *p's* <.01). The cognitive composite *Generativity* was significantly negatively correlated with the BRIEF Teacher (a) Inhibit ($p < .001$) and (b) Initiate, Working Memory, Plan/Organize, and Monitor (all *p's* < .01). The cognitive composite *Working Memory* was significantly negatively correlated with

BRIEF Teacher Plan/Organize ($p < .01$). The cognitive composite of *Processing Speed* was not significantly correlated with any of the BRIEF Teacher clinical scales.

Table 24

Control Group: Correlations between Composite Cognitive Scores and BRIEF Teacher Raw Scores

Composite Cognitive Score / BRIEF Teacher Raw Score	Attentional Control	Generativity	Working Memory	Processing Speed
Inhibit	-.463***	-.245***	-.148	-.017
Shift	-.393**	-.250*	-.296*	-.082
Emotional Control	-.511***	-.180	-.172	-.055
Initiate	-.313**	-.339**	-.261*	-.053
Working Memory	-.321**	-.411**	-.235*	-.044
Plan/Organize	-.340**	-.361**	-.307**	-.092
Organization of Materials	-.215*	-.125	-.185	-.036
Monitor	-.263**	-.375**	-.212	-.063

Note. Data presented are Pearson *r* correlation coefficients.

*$p < .05$. **$p < .01$. ***$p < .001$.

For the control group on the BRIEF Teacher, none of the composite cognitive domains were predictors of Initiate or Organization of Materials. The composite cognitive domain of *Attentional Control* was the only significant predictor of Inhibit and Emotional Control, explaining 21.5% and 26.1% of the variance, respectively. Although the overall model containing the composite cognitive scores *Working Memory* and *Attentional Control* was significant for Shift, and these variables explained 20.2% of the variance, only *Attentional Control* was a significant predictor of this measure. The composite cognitive domain of *Generativity* was the only significant predictor of Working Memory, accounting for 16.9% of the variance. For Plan/Organize and Monitor, the overall model containing all the composite cognitive scores was significant, and these variables explained 22.8% and

21.5% of the variance, respectively. However, individually, none of the composite cognitive scores were significant predictors of these BRIEF Teacher measures (see Table 25 and Table 26).

Table 25

ANOVA Summary Table for Regression Models: Control Group, BRIEF Teacher

BRIEF Teacher measure	SS	df	MS	*F*	*p*
Inhibit					
Model: Attentional Control	248.57	1, 60	248.57	16.13	<.001***
Shift					
Model: Working Memory and Attentional Control	217.47	2, 60	108.73	7.32	.001**
Emotional Control					
Model: Attentional Control	174.19	1, 60	174.19	20.86	<.001***
Initiate	149.64	4, 60	37.41	3.28	.017
Working Memory					
Model: Generativity	216.29	1, 60	216.29	11.98	.001**
Plan/Organize					
Model: All variables	351.03	4, 60	87.76	4.13	.005**
Organization of Materials	22.86	4, 60	5.72	1.03	.400
Monitor					
Model: All variables	271.24	4, 60	67.81	3.84	.008**

***p < .01. ***p < .001.*

Table 26

Coefficients for Significant Regression Models: Control Group, BRIEF Teacher

Model	B	SE	*β*	*t*	*p*
BRIEF Teacher Inhibit	-4.30	1.07	-.46	-4.02	<.001***
Constant	14.54	0.51	-	28.66	<.001***
Attentional Control	-4.30	1.07	-.463	-4.02	<.001***
BRIEF Teacher Shift					
Constant	15.28	0.50	-	30.69	<.001***
Attentional Control	-3.10	1.08	-3.46	-2.88	.006**
Working Memory	-1.34	0.72	-.22	-1.86	.069
BRIEF Teacher Emotional Control					
Constant	12.18	0.37	-	32.62	<.001***
Attentional Control	-3.60	0.79	-.51	-4.57	<.001***
BRIEF Teacher Working Memory					
Constant	16.87	0.54	-	30.99	<.001***
Generativity	-2.70	0.78	-.41	-3.46	<.001***
BRIEF Teacher Plan/Organize					
Constant	17.61	0.60	-	29.53	<.001***
Attentional Control	2.24	1.37	-.21	-1.64	.107
Generativity	-1.81	0.91	-.25	-1.99	.051
Working Memory	-1.58	0.88	-.22	-1.79	.079
Processing Speed	0.06	0.66	.01	0.09	.930
BRIEF Teacher Monitor					
Constant	16.66	0.54	-	30.66	<.001***
Attentional Control	-2.43	1.25	-.25	-1.95	.056
Generativity	-1.76	0.83	-.27	-2.13	.037*
Working Memory	-0.75	0.80	-.12	-0.94	.352
Processing Speed	0.15	0.60	.03	0.25	.801

Note. *$p < .05$. ***$p < .001$.

Testing Hypothesis 4.2

Parent Ratings for the FASD Group. In general, the pattern of correlations in Table 27 shows that, for the FASD group, better performance on the composite cognitive domains *Attentional Control*, *Generativity*, and *Processing Speed* were associated with fewer executive difficulties in daily life, as rated by parents. For the composite cognitive domain *Working Memory*, better performance was associated with more severe executive difficulties in daily life. However, none of the cognitive composite scores significantly correlated with any of the BRIEF Parent clinical scales at my more stringent alpha level of 0.01.

Table 27

FASD Group: Correlations between Composite Cognitive Scores and BRIEF Parent Raw Scores

Composite Cognitive Score / BRIEF Teacher Raw Score	Attentional Control	Generativity	Working Memory	Processing Speed
Inhibit	.015	.140	.085	-.177
Shift	-.011	-.100	.153	-.027*
Emotional Control	-.154	.033	.009	-.171
Initiate	-.001	-.174	.127	-.111
Working Memory	-.054	-.275*	.024	-.142
Plan/Organize	-.195	-.292*	.151	-.123
Organization of Materials	-.093	-.019	.064	-.140
Monitor	-.239	-.209	.028	-.114

Note. Data presented are Pearson *r* correlation coefficients.

*$p < .05$.

As shown in Table 28, regression analyses revealed that none of the composite cognitive scores were significant predictors of scores on any of the BRIEF Parent clinical scales in the FASD group.

Table 28

ANOVA Summary Table for Regression Models: FASD Group, BRIEF Parent

BRIEF Parent measure	SS	*df*	MS	*F*	*p*
Inhibit	91.29	4,47	22.82	0.87	.488
Shift	31.21	4,47	7.80	0.46	.764
Emotional Control	75.73	4,47	18.93	0.78	.542
Initiate	34.24	4,47	8.56	0.73	.575
Working Memory	112.15	4,47	28.04	0.97	.432
Plan/Organize	298.77	4,47	74.69	1.93	.123
Organization of Materials	30.32	4,47	7.58	0.46	.767
Monitor	72.88	4,47	18.22	1.05	.395

Note. All ANOVA summaries are for the full model (i.e. with all four cognitive composite scores as predictors).

Parent Ratings for the Control Group. In general, the pattern of correlations in Table 29 shows that, for the control group, better performance on all four composite cognitive scores (*Attentional Control*, *Generativity*, *Processing Speed* and *Working Memory*) was associated with fewer executive difficulties in daily life, as rated by parents. The cognitive composite *Generativity* was significantly negatively correlated with the BRIEF Parent Working Memory, Plan/Organize, and Monitor scales (all p's $< .01$).

Table 29

Control Group: Correlations between Composite Cognitive Scores and BRIEF Parent Scores

Composite Cognitive Score / BRIEF Parent Score	Attentional Control	Generativity	Working Memory	Processing Speed
Inhibit	-.160	-.249*	-.205	-.030
Shift	-.268*	-.221*	-.209	-.040
Emotional Control	-.154	-.248*	-.132	-.154
Initiate	-.221*	-.249*	-.066	-.002
Working Memory	-.263*	-.343**	-.068	-.048
Plan/Organize	-.230*	-.320**	-.073	.042
Organization of materials	.092	-.061	.165	.077
Monitor	-.191	-.334**	-.093	-.035

Note. Data presented are Pearson *r* correlation coefficients.

*$p < .05$. **$p < .01$.

As shown in Table 30, regression analyses revealed that, for the control group, none of the composite cognitive scores were significant predictors of scores on any of the BRIEF Parent clinical scales.

Table 30

ANOVA Summary Table for Regression Models: Control Group, BRIEF Parent

BRIEF Parent measure	SS	df	MS	*F*	*p*
Inhibit	112.67	4, 57	28.17	1.31	.278
Shift	74.68	4, 57	18.69	1.61	.184
Emotional Control	93.32	4, 57	23.33	1.21	.318
Initiate	68.00	4, 57	17.00	1.20	.320
Working Memory	197.34	4, 57	49.33	2.14	.089
Plan/Organize	254.49	4, 57	63.62	1.92	.121
Organization of Materials	34.38	4, 57	8.59	.066	.622
Monitor	91.49	4, 57	22.87	1.76	.151

Summary. When examining the results for the FASD group on the BRIEF Teacher, two composite cognitive measures (i.e. domains) of executive function emerged as predictors

of executive difficulties in daily life. These were *Attentional Control* and *Generativity*. *Attentional Control* explained 22% of the variance in Emotional Control, and *Generativity* explained 23% of the variance in Initiate. The model containing *Processing Speed* and *Generativity* explained 30% of the variance in Working Memory, 25% of the variance in Plan/Organize, and 24% of the variance in Organization of Materials; however, only *Generativity* was uniquely related to these three BRIEF Teacher variables. The model containing the cognitive composite measures of *Working Memory*, *Attentional Control* and *Generativity* significantly predicted 32% of the variance in Monitor. However, only *Generativity* was uniquely related to Monitor. When examining the results for the FASD group on the BRIEF Parent, none of the composite cognitive scores was a significant predictor of executive difficulties in daily life, as rated by parents.

When examining the results of the control group on the BRIEF Teacher, the composite cognitive domain *Attentional Control* was a significant predictor of Inhibit (21.5%) and Emotional Control (26.1%). The cognitive composite scores *Working Memory* and *Attentional Control* significantly predicted Shift (20.2%). However, only *Attentional Control* was uniquely related to Shift. The composite cognitive domain of *Generativity* was the only significant predictor of Working Memory (16.9%). While the model containing all four composite cognitive scores was predictive of Plan/Organize (22.8%) and Monitor (21.5%), none of the individual composite cognitive scores was uniquely related to either of these two variables. As in the case of the FASD group, none of the composite cognitive scores were significant predictors of executive difficulties in everyday life, as rated by parents.

Chapter Six: Discussion

The Impact of Low SES on Executive Function in Typically Developing Adolescents

As expected, this sample of typically developing adolescents from a low-SES community (the control group) performed significantly worse on most measures of executive function relative to international norms on both the D-KEFS and the CANTAB. On the D-KEFS, the control group obtained mean scaled scores ranging from five to seven on most subtests, which is more than one standard deviation below the mean of ten. These results are comparable to the findings of previous studies indicating that the performance of children in LMICs is, in general, approximately one standard deviation below that of children in MHICs on neuropsychological measures and tests of general intelligence (Mulenga et al., 2001; Pienaar et al., 2016; Skuy et al., 2000; Van der Merwe, 2008; Van Tonder, 2007). In these countries, the combined effects of socioeconomic deprivation, race, degree of acculturation to Western values, and urbanisation have a profound impact on neuropsychological test performance (Ferrett, Carey, et al., 2014).

In this study, the control group exhibited particularly poor performance (more than one standard deviation below the normative mean) on the Number-Letter Switching Condition of the Trail Making Test and the Twenty Questions Test. This suggests that these two measures may be especially sensitive to the impact of low socioeconomic status or inappropriate for the South African cultural context. Several factors may account for these findings.

Cultural values that prioritise accuracy over speed might have contributed to the control group's poor performance on the Trail Making Test. Previous studies have shown cultural differences in performance on timed neuropsychological tests, with individuals from

Western countries (e.g. the United States of America) performing significantly faster than individuals from other countries such as Russia, Argentina, and Africa (Agranovich et al., 2011; Cores et al., 2015; Ferrett, Thomas, et al., 2014; Mulenga et al., 2001). For example, in their study investigating the performance of urban middle-class literate Zambian children on the NEPSY, Mulenga et al. (2001) found that their sample's performance on most subtests was in keeping with U.S. norms, except for the timed component of measures of visual attention and speeded naming, which were one standard deviation below the mean. Similarly, Ferrett, Thomas, et al. (2014) found that 12- to 15- year old Afrikaans- and English-speaking adolescents from the Cape Town region in South Africa (i.e. the same population the current sample was drawn from) performed significantly slower on the Children's Color Trails Test, a timed measure of divided attention and sequencing, compared to international norms. In fact, the mean completion times were slower than previously published international data for adolescents with ADHD and mild brain injury (Ferrett, Thomas, et al., 2014). In the present study, the control group performed significantly below international norms not only on the Number-Letter Switching Condition but also on the other components of the Trail Making Test (i.e. the Visual Scanning and Letter Sequencing conditions). This suggests that this sample of typically developing adolescents may have poorly developed visual scanning and letter sequencing skills compared to the U.S. standardisation sample, and that their poor performance on the Number-Letter Switching condition was influenced by poor baseline (i.e. non-executive) abilities. Furthermore, it is worth noting that despite their poor performance in general, the error scores for the control participants on the Trail Making Test were either in keeping with international norms or significantly better (i.e. this sample of typically developing adolescents did not make an elevated number of errors relative to international norms or made significantly fewer errors). One possible explanation for this is that despite being instructed to work as fast as possible on these timed tests, the participants worked

slowly but accurately, leading to slow completion times but low error scores. Although more research is required to test this hypothesis, it is possible that Western values around speed of output are not as strongly endorsed in this population of Coloured participants.

Another potential factor contributing to the control group's poor performance on the Letter Sequencing and Number-Letter Sequencing Conditions of the Trail Making Test is a poor grasp of the alphabetical sequence due to educational factors. Previous studies have shown that reading ability, which is also a measure of educational quality, accounts for a greater amount of variance than years of education on several tests of executive function, such as Similarities, COWAT, Trail Making Test, and Colour Progressive Matrices (Johnson et al., 2006). South Africa is characterised by huge disparities in terms of the quality of education children receive due to the legacy of the former Apartheid regime, which implemented separate schooling for Black and Coloured children under the Department of Education and Training (DET) with separate syllabi and examinations to those of private and White government schools (referred to as Model C schools). The latter schools were modelled on the British public school system and were well resourced, while DET schools had poorer facilities, higher student-to-teacher ratios, under-qualified staff, and a lack of materials such as books, desks, and stationery. Although the Apartheid government was abolished in 1994, the consequences of these separate and unequal education policies persist, with major differences in the quality of education offered at former DET schools (Kahn, 2004; Motala, 2006; Reddy et al., 2022). In 2016, the Progress in International Reading Literacy Study (PIRLS), which assessed reading comprehension across 50 countries, found that 78% of South African Grade 4 children were unable to read for meaning or retrieve basic information from a text to answer simple questions. Most learners came from disadvantaged backgrounds (75%), and significant differences in achievement were found between those from disadvantaged backgrounds and those from more affluent backgrounds. Furthermore,

the study showed that the majority (94%) of learners attended schools where resource shortages affected instruction to some extent. Learners living in remote rural villages, small towns or villages, and townships had the lowest literacy achievement (Howie et al., 2017).

In the present study, the majority of the control participants were in Grade 8 (i.e. the first year of high school under the South African education system) when assessed at Time 1 and attended former DET schools. Qualitative clinical observations during the assessments of these adolescents suggest that many were unable to recite the alphabet, even when not under time constraints, or did so hesitantly, often switching between Afrikaans and English while doing so. This suggests that this basic skill had not yet been adequately consolidated. To determine which letter comes next, individuals with a relative weakness in the basic verbal skill of letter sequencing must recite or sing the alphabet starting with A until they arrive at the letter required. This repeated recitation of the alphabet could add a significant amount of time to test performance and lead to slow completion times on both the Letter Sequencing task and Number-Letter Switching condition of the Trail Making Test (Delis et al., 2001).

With regard to the Twenty Questions Test, an adequate performance depends not only on executive function skills, but also on basic cognitive skills required for the initial processing and identification of objects in the stimulus array, including visual attention and perception, object recognition, and object naming. In addition, the higher-order executive skill of categorisation is required, whereby the examinee is able to perceive verbal or visual features that are common to a subset of objects among those depicted on the stimulus page and form a higher-level concept that captures the defining properties of that subgroup (Delis et al., 2001). However, this executive process relies on a well-developed vocabulary. For example, to classify the fork, spoon, and bowl as “dinnerware” or “tableware,” the individual must possess one of these words in their lexicon. Consistent with previous South African

studies examining educationally disadvantaged participants' performance on IQ tests (Pienaar et al., 2016; Shuttleworth-Edwards et al., 2004; Van Tonder, 2007), the mean WISC-IV Verbal Comprehension Index score of the control group was 67.23 (SD = 12.92). This suggests that poorly developed language and verbal reasoning skills relative to the U.S. standardisation sample may at least partially account for the control group's very poor performance on the Twenty Questions Test.

The finding of a particularly poor performance on verbal measures of executive function, such as the Twenty Question Test, is also in keeping with the findings of previous studies indicating that lower levels of parental education are associated with worse scores on verbal tests of executive function (Aarnoudse-Moens et al., 2013; Ardila et al., 2005). In the present study, the mean maternal level of education for the control group was only 7.9 years (SD = 2.7). However, the control participants performed poorly on the non-verbal tests of executive function. Significant differences were found between the control group's performance and international norms on the SWM and IED of the CANTAB, measures of spatial working memory, and cognitive flexibility. This is consistent with the findings of Cave and Grieve (2009), who demonstrated significant differences between South African children with a high quality of education (private schools) and those with a low quality of education (former DET schools) on both verbal and nonverbal tests of executive function (Cave & Grieve, 2009). Nonverbal neuropsychological tests are often assumed to be more culturally fair than verbal tests. However, several previous studies have demonstrated that performance on nonverbal tests is also influenced by SES, education, and culture (see Roselli & Ardila, 2003 for review).

Language and executive function have been shown to be particularly sensitive to the impact of poverty relative to other domains of cognition, such as memory and visuo-

perceptual functions (Noble et al., 2005). Two previous studies (Noble et al., 2007; Noble et al., 2005) found that language abilities accounted for the association between SES and performance on executive function tests in preschoolers. This raises the possibility of a causal pathway whereby differences in SES influence language development, which then independently drives the development of executive function abilities (Noble et al., 2005). Parents with higher levels of education and greater access to resources due to higher SES tend to utilise a more extensive vocabulary, supporting language development (Fatima et al., 2016). In contrast, low-SES families face ongoing financial hardships that may negatively impact parents' ability to meet their children's needs. This extends beyond material provisions to include emotional support and intellectual stimulation, ultimately affecting cognitive development (Mezzacappa, 2004). Social interactions during infancy appear to support the development of certain aspects of executive function, such as attentional control and inhibition (Morgan et al., 2021). In older children, language skills may support the use of inner speech, which in turn supports the use of metacognitive strategies to keep track of instructions and support problem-solving approaches on both verbal and non-verbal tasks (Bishop et al., 2014; Marcovitch & Zelazo, 2006).

The Structure of Executive Function

A PCA was performed to reduce the number of cognitive variables to obtain a better understanding of the components or domains of executive functioning in this sample of typically developing adolescents from a low-SES community. Intercorrelations among the different executive function measures were fairly low, with 12 variables excluded from further analysis because they correlated below 0.3 with any other variable. Low correlations between measures of executive function have repeatedly been reported in both adult (Miyake

et al., 2000) and child samples (Lehto et al., 2003; Rose et al., 2011; St Clair-Thompson & Gathercole, 2006; Wu et al., 2011).

In the present study, a four-factor solution explaining 58.5% of the variance was the best fit for the data. In keeping with this, previous studies have generally found complex tests of executive function to load on three to four factors (Brocki & Bohlin, 2004; Lehto et al., 2003; Levin et al., 1991; Welsh et al., 1991).

Five variables had the highest loadings on the first factor. This included two measures of verbal fluency (Letter Fluency, Category Fluency) and three measures of nonverbal fluency (Design Fluency Filled Dots, Designed Fluency Empty Dots, Design Fluency Switching). Because these tasks all require the examinee to generate novel material while observing several rules (Delis et al., 2001), this factor was named *Generativity*.

The second factor received its highest loadings for responses that were too early on the CANTAB Simple Reaction Time task (SRT Total Commission Errors), responses that were too late on the SRT (SRT Total Omission Errors), an overall score reflecting efficiency at completing the IED (IED Total Errors Adjusted), and performance on the Tower Test (Tower Test Total Achievement Score). Anderson (2002) proposed a domain of executive function he called Attentional Control, which includes selective attention, self-monitoring of behaviour to minimise errors, and the ability to inhibit impulsive responses. The CANTAB SRT task measures general alertness or attention. An elevated number of omission errors suggests inattention, whereas elevated commission errors suggest impulsive responding (Cambridge Cognition, 2014). The IED measures rule acquisition and attentional set shifting, with the Total Errors Adjusted score proving an indication of the subject's efficiency in attempting the test, that is, their ability to minimise errors (Cambridge Cognition, 2014). While the D-KEFS Tower Test and its variants (the Tower of London task and Tower of

Hanoi task) are often described as measures of planning or goal setting, previous factor analytic studies suggest that a good performance on these tasks requires the inhibition of prepotent responses (Lehto et al., 2003; Miyake et al., 2000). Because these tasks all require sustained attention and the ability to inhibit automatic responses, this factor was named *Attentional Control*.

Three outcome measures from the CANTAB Spatial Working Memory task loaded on the third factor (SWM Between Errors, SWM Within Errors, SWM Strategy). In addition, repeated responses on the Twenty Questions test (Twenty Questions: Repeated Questions) also loaded on this factor. The Spatial Working Memory task assesses the ability to hold and simultaneously manipulate information in the mind. A tendency to repeat questions on the Twenty Question test suggest impaired feedback utilisation (Delis et al., 2001). While a variety of underlying deficits, such as difficulties inhibiting prepotent responses and attentional dysfunction, may account for an elevated number of repeat questions on this task (Delis et al., 2001), it is also likely that difficulties holding previous responses in mind may contribute to this. This factor was therefore named *Working Memory*.

Processing Speed: Two variables (CRT Mean Latency, SRT Mean Latency) loaded on the fourth factor. Both variables measure response speed, and this factor was therefore named *Processing Speed*.

While these findings broadly support the executive function model proposed by Anderson (2002), particularly in terms of the presence of attentional control and processing speed domains, there are also notable discrepancies. For example, measures of verbal fluency, which in this instance clustered with nonverbal fluency tasks, are typically considered under the cognitive flexibility domain (V. A. Anderson et al., 2008). However, so are measures of working memory (Anderson, 2002, 2008) which emerged as a separate factor

in the present study. No clear goal-setting domain was identified in the present study. A lack of commonality between the factor structures identified in various studies is quite common (Lehto et al., 2003), and highlights the difficulties in interpreting neuropsychological tests, as discussed in detail above.

Development of Executive Function in Adolescents Exposed to Alcohol Parentally

After controlling for non-verbal IQ, no significant differences were found between the FASD and control groups for the Generativity, Attentional Control or Processing Speed domains. Working Memory was not influenced by non-verbal IQ, and the FASD group performed significantly worse than controls. The finding of significant difficulties in working memory is in keeping with meta-analyses conducted by Khoury et al. (2015) and Kingdon et al. (2016), which demonstrated moderate impairments in working memory for FASD groups compared to controls.

However, the lack of significant differences between the FASD and control groups in all other domains is surprising. These findings contradict those of two meta-analyses which suggest that the strongest and most significant impairments for FASD groups compared to controls are in the domains of set-shifting (Khoury et al., 2015; Kingdon et al., 2016), planning (Kingdon et al., 2016), and fluency (Kingdon et al., 2016). Direct comparisons between these findings and those of the present study are difficult due to slight differences in the terminology used and differences in the way test measures were allocated to each domain. For example, while both Kingdon et al. (2016) and Khoury et al. (2015) allocated the CANTAB IED task to Set-shifting, Khoury et al. (2015) also included the D-KEFS Verbal Fluency and Design Fluency tasks under this domain, whilst Kingdon et al. (2016) allocated these tasks to a separate Fluency domain (similar to the Generativity domain in the present study). This highlights the need for consensus in the research and clinical community

regarding how we define different aspects of executive function and the need for clarity on what complex tasks of executive function really measure (Miyake et al., 2000).

In the present study, Working Memory was the only domain for which nonverbal IQ was not a significant covariate. The relationship between IQ and executive function is the subject of intense debate, with some theorists arguing that IQ should not be used as a covariate in studies examining neurodevelopmental disorders (Dennis et al., 2009). However, some researchers contend that IQ should be statistically adjusted for to verify that group differences in executive function are not merely due to variations in IQ (Kingdon et al., 2016). While children with FASD display more executive deficits than typically developing controls when groups are matched for intellectual functioning (Kingdon et al., 2016), there is also evidence that large differences in IQ scores (with non-FASD groups having higher IQ scores than FASD groups) produce larger effects for at least some domains of executive function (Khoury et al., 2015). In the present study, the control group ($M = 80.24$, $SD = 10.80$) had a significantly higher nonverbal IQ than the FASD group ($M = 71.29$, $SD = 9.47$). It may be that differences between the two groups in other domains of executive function were obscured by controlling for nonverbal IQ.

With regard to the longitudinal component of the study, there was no time effect, nor a time by group interaction for any of the domains, suggesting no major developmental change in the 18-month period in either group. This finding is unexpected. Previous studies suggest that executive function undergoes rapid development during infancy and early childhood, while adolescence and early adulthood are characterised by more subtle improvements and refinement of these skills (Anderson, 2008). This sample of adolescents (both FASD and controls) was approximately 14 years old at Time 1 and 16 years old at Time 2. It is therefore possible that their developmental trajectory had already started to

plateau and that the 18-month period between assessments was too short to see major improvements in executive function. However, previous studies have found a spurt in the development of attentional capacity and cognitive flexibility (Anderson, Anderson, et al., 2001) as well as improvements in working memory, planning and problem solving (De Luca et al., 2003; Luna et al., 2004) in similar age groups, which argues against this. Another hypothesis is that these adolescents' low SES environment has 'suppressed' the development of their executive function and that these skills may develop at a slower rate than adolescents from more socially advantaged environments. This highlights the need for more research into the developmental trajectory of executive function in children from low-SES backgrounds, including children with neurodevelopmental disorders such as FASD.

FASD and Deficits on Behavioural Measures of Executive Function

Adolescents with FASD demonstrated profound executive functioning deficits on the BRIEF. A significantly greater proportion of the FASD group obtained scores in the clinically impaired range (i.e. *t* scores ≥ 65) on the BRI, MI, and GEC relative to the control group. These results are broadly consistent with those of previous studies reporting significant differences between FASD groups and either the BRIEF standardisation sample (Knuiman et al., 2015; Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2006; Rasmussen et al., 2007) or a study-specific sample of typically developing children (McGee et al., 2008; Nguyen et al., 2014; Wozniak et al., 2013).

On the BRIEF Teacher, 59.6%, 85.4% and 80.9% of the FASD group obtained scores in the clinically impaired range for the BRI, MI, and GEC respectively. The BRIEF Teacher has only been used in three previous studies with FASD samples (Rasmussen et al., 2006; Stevens et al., 2013; Taylor & Enns, 2019), and only one study (Taylor & Enns, 2019) reported the percentage of children with scores in the impaired range (see Table 31). The

present results are in keeping with those reported by Taylor and Enns (2018) who found that 75% of alcohol exposed children who received a diagnosis of FASD and 62% of those who were exposed but did not meet diagnostic criteria obtained scores in the impaired range on the GEC.

On the BRIEF Parent, 41.7%, 43.8% and 47.9% of the FASD group obtained scores in the clinically impaired range for the BRI, MI, and GEC respectively. Knuiman et al. (2015), found similar rates of impairment in their sample of Polish children with FASD. However, in the present study, the percentage of children who obtained scores in the impaired range was substantially lower than those in several other studies (Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2007). The relatively low rates of impairment on parent report raises the possibility that severe executive deficits are less common in this sample of children with FASD than what has been detected previously. However, it is worth noting that the rates of impairment obtained on the BRIEF Teacher were similar to those obtained on the BRIEF Parent in the majority of previous studies (Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2007), which argues against this. Moreover, previous studies on FASD samples have found that, in general, teachers report more behavioural problems than parents (Taylor & Enns, 2019; Tsang et al., 2016). Although there is limited literature comparing parent and teacher ratings on the BRIEF, at least one study found that teachers reported significantly more executive difficulties than did parents (Rasmussen et al., 2006). One possible reason for this is that the classroom environment may place more demands on children's executive function (Rasmussen et al., 2006). However, it is equally possible that teachers are more astute at detecting problems in children's ability to implement executive function skills by virtue of their training and having more opportunities to compare children against their peers (Rasmussen et al., 2006; Taylor & Enns, 2019).

Maternal levels of education for the FASD group were particularly low, with most mothers having less than six years of formal education (M = 5.4 years), and significantly less education than mothers of children in the control group. Although mothers were supported in completing the questionnaire by having a research assistant read them the questions, it is possible that low levels of education may have impacted on their ability to understand and accurately respond to the questions or on their capacity to reflect on what would constitute 'typical' behaviour. Moreover, there is uncertainty regarding whether the BRIEF assesses identical constructs in this cultural setting as it does in the standardisation sample, particularly within the home environment. A recent systematic review examining the application of the BRIEF in LMICs revealed strong evidence supporting its internal consistency and construct validity. However, the evidence for its construct validity was rated low to moderate in quality. Limited evidence was found for good content, structural, and cross-cultural validity (Kusi-Mensah et al., 2022). Merely translating neuropsychological assessments and behavioural questionnaires is insufficient to make them suitable for use in LMICs. To ensure their effectiveness, these tools must also undergo cultural adaptation to fit the specific context in which they will be employed. "Concept formation is goal-directed. Which means, if the socio-cultural milieu within which a child is placed does not place certain types of goals before him/her, he/she will not form concepts to solve the problems standing as obstacles to that goal…" (Kusi-Mensah et al., 2022, p. 999).

Regarding the clinical scales, scores in the clinically impaired range occurred most frequently on the Working Memory scale (62.5%), followed by the Plan/Organize scale (47.9%) on the BRIEF Parent. A similar pattern was observed on the BRIEF Teacher, with scores in the clinically impaired range occurring most frequently on the Plan/Organize scale (85.4%), followed by the Working Memory scale (77.1%). These findings are consistent with prior studies which suggest that children with FASD exhibit greatest difficulty on the

Working Memory scale (Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2006; Rasmussen et al., 2007). The Working Memory scale has also been found to be the best predictor for distinguishing between groups of children who are alcohol-exposed and have ADHD, alcohol-exposed without ADHD, non-exposed with ADHD, and typically developing control participants (Nguyen et al., 2014).

Previous studies have generally found that FASD samples show the least impairment on the Organization of Materials scale (Knuiman et al., 2015; McGee et al., 2008; Mohamed et al., 2019; Rai et al., 2017; Rasmussen et al., 2006; Rasmussen et al., 2007). While parent ratings in the present study were consistent with this, low rates of impairment were also observed on the Initiate scale of the BRIEF Parent, which has typically been found to be one of the areas of greatest difficulty for FASD samples (McGee et al., 2008; Rasmussen et al., 2007). On the Teacher Form, the lowest rates of impairment were observed on the Inhibit (41.7%) and Emotional Control (41.7%) scales. The FASD and control groups did not differ significantly from each other on these two scales either. The reasons for these discrepant findings remain unclear. At least one Canadian study found that Aboriginal and Caucasian children with FASD present with slightly different patterns of neuropsychological strengths and weaknesses (Rasmussen et al., 2006). It is therefore possible that cultural differences in behavioural expectations or neuropsychological profiles may account for this sample of FASD participants' tendency to exhibit fewer difficulties independently generating ideas or problem-solving strategies at home and less difficulty resisting impulses and modulating their emotional responses at school compared with samples from other countries.

Table 31

Percentage of Participants in the FASD group with BRIEF Scores in the Clinically Impaired Range

	Present study		Rasmussen et al. (2007)	Knuiman et al. (2015)	Rai et al. (2017)	Taylor and Enns (2019)		Mohamed et al. (2019)
BRIEF Scale	(*n* = 48)	(*n* = 48)	(*n* = 64)	(*n* = 37)	(n= 52)	(*n* = 116)	(*n* = 94)	(*n* = 49)
	Parent	Teacher	Parent	Parent	Parent	Parent	Teacher	Parent
Inhibit	31.3%	41.7%	75.0%	62%	73.1%	-	-	87.8%
Shift	35.4%	72.3%	71.7%	41%	75.0%	-	-	77.6%
Emotional Control	37.5%	41.7%	65.6%	35%	69.2%	-	-	77.6%
†BRI	41.7%	59.6%	86.9%	-	73.1%	-	-	87.8%
Initiate	22.9%	72.9%	79.4%	32%	69.2%	-	-	81.6%
Working Memory	62.5%	77.1%	78.1%	43%	82.7%	-	-	93.9%
Plan/Organize	47.9%	85.4%	59.6%	16%	75.0%	-	-	93.9%
Organization of Materials	22.9%	54.2%	66.1%	5%	76.9%	-	-	63.3%
Monitor	37.5%	72.9%	68.9%	24%	55.8%	-	-	85.7%
ΔMI	43.8%	85.4%	84.5%	-	80.8%	-	-	89.8%
□GEC	47.9%	80.9%	86.5%	46%	86.5%	75%	81%	91.8%

Note. The cut-off for impairment is $t \geq 65$. †BRI = Behavioral Regulation Index. ΔMI = Metacognition Index. □GEC = Global Executive Composite.

After controlling for covariates on the BRIEF, significant differences were found between the FASD and control groups on the Plan/Organize, Monitor, and GEC of the BRIEF Parent, with the FASD group being rated as displaying significantly more difficulties than controls. On the BRIEF Teacher, the FASD group displayed more difficulties compared to controls on the Emotional Control and Organization of Materials clinical scales only. As in the case of neuropsychological data, maternal level of education was not a significant predictor of the severity of executive difficulties reported by either parents or teachers. However, non-verbal IQ was a significant predictor of the severity of executive difficulties on one of the clinical scales (Monitor) of the BRIEF Parent, six of the clinical scales (Inhibit, Shift, Initiate, Working Memory, Plan/Organize, and Monitor), and the GEC of the BRIEF Teacher. This suggests that, as in the case of performance on neuropsychological tests of executive function, nonverbal IQ may be an important mediating factor influencing the extent of executive difficulties displayed by children in their daily lives.

Relationship Between Neuropsychological Measures of Executive Function and the Executive Function in Everyday Life

There were no significant correlations between the four composite executive function scores and parent ratings of everyday executive function in the FASD group. In the control group, Generativity was weakly corrected with the Working Memory, Plan/Organize, and Monitor scales of the BRIEF Parent, but none of the composite cognitive scores were significant predictors for any of the BRIEF scores. These findings are consistent with previous studies that demonstrated little to no correlation between neuropsychological measures and parent ratings of executive function in FASD samples (Bernes et al., 2021; Gross et al., 2015; Mohamed et al., 2019; Rai et al., 2017).

Only one previous study (Bernes et al., 2021) examined the relationship between performance-based measures of executive function and BRIEF Teacher ratings in FASD. They matched the clinical scales of the BRIEF to neuropsychological measures purported to measure similar constructs. For the alcohol-exposed group, a significant but weak correlation was found between teacher ratings of working memory and a neuropsychological measure of the same ability. For the control group, significant but weak correlations were found between teacher ratings of working memory, the ability to develop steps to complete tasks in a systematic manner, and self-monitoring skills and performance on neuropsychological measures of the same abilities. In contrast, the present study found several weak to moderate negative correlations between teacher ratings of everyday executive function and composite executive function scores for both the FASD and control groups.

Specifically, stronger negative correlations were observed between the executive domains, Attentional Control and Generativity, and a number of clinical scales from the BRIEF Teacher. Higher Attentional Control scores predicted a better ability to regulate emotional responses appropriately in the classroom for the FASD group. Higher Generativity scores predicted better ability to generate ideas independently, hold information in mind while completing tasks (i.e. working memory), the ability to set goals and develop steps to complete tasks in a systematic manner, and adolescents' ability to keep their workspace or belongings tidy in the classroom. Similarly, for the Control group, higher Attentional Control scores predicted a better ability to inhibit impulsive responses, regulate emotions appropriately, and shift flexibly from one situation or activity to the next in the classroom. Higher Generativity scores predicted a better ability to hold information in mind while completing tasks. These results suggest that teacher ratings of executive function may provide a better understanding of the relationship between performance-based measures and

behaviour ratings of executive function than parent ratings, possibly because of the demands of the classroom.

Differences in methodology might account for our somewhat discrepant findings compared to those of Bernes et al. (2021). While they analysed domain-specific correlations between the BRIEF clinical scales and neuropsychological tests purporting to measure the same construct, the present study did not. The present study also used composite executive domains rather than just one measure of a specific domain. Further research is required to replicate the findings of this study.

Limitations, Implications, and Future Directions

Certain limitations of this study should be addressed in future research. This research concentrated on a limited age range (between age 13 and 16 years) and did not examine the trajectory of executive function development in children with FASD from infancy to adulthood. This narrow age band, combined with the relatively small sample size, may not have allowed for the accurate identification of developmental changes during adolescence in either typically developing or alcohol-exposed adolescents. It might be helpful for future longitudinal studies to include a wider age range of children and adolescents and to assess executive function at multiple time points, especially since a large body of developmental research suggests that executive function undergoes rapid development during early and middle childhood, with adolescence being characterised by more subtle improvements in attention, working memory, cognitive flexibility, and planning which may be difficult to detect over relatively short intervals (Anderson, Anderson, et al., 2001; De Luca & Leventer, 2008; Luna et al., 2004).

Maternal alcohol consumption has both social and neurobiological consequences. Children living in an environment where alcohol abuse is prevalent frequently experience

disrupted lives, marked by recurrent changes in placement, exposure to substance abuse, domestic violence, and mental health issues within the household (Flannigan et al., 2021; Korkman et al., 2003; Tan et al., 2022). Consequently, these children are at increased risk of neglect and abuse. Several participants in this study were in foster care, with a significantly greater proportion of these children being in the FASD group. The adequacy of these placements was not established, nor was the adequacy of care received by children still living with their biological parents. Childhood exposure to familial trauma, such as physical abuse or witnessing domestic violence, has been found to be associated with worse performance on executive function tests (DePrince et al., 2009; Lund et al., 2020).

Conversely, there is some evidence that higher SES and stable caregiving can mitigate the impact of PAE on cognitive function and behaviour (Coles et al., 2020). In addition, certain parental styles appear to support the development of executive function skills in children with FASD. For example, in a study examining the relationship between parental styles and executive function in children with FASD, Mattson et al. (2022) found that parents tended to use a more goal-directed interaction style (particularly interactions that have an increased achievement-orientation), and that this was related to emerging executive function. The authors hypothesised that parents may be scaffolding executive function skills in their children by incorporating more frequent goal-directed behaviours into their interaction style. Parents from SES backgrounds may have enhanced access to resources, including literature and professional guidance, which could enable them to more effectively foster the development of their children's emotional and behavioural self-regulation skills.

It is possible that psychosocial factors, including exposure to early developmental trauma and neglect, may have affected the development of executive function in this sample. This study cannot exclude the influence of potential confounding variables in the association

between SES and executive function in the context of FASD, including the home-learning environment, parent-child interactions, child and parental stress, and access to supportive services. The challenge of accounting for the effects of suboptimal social environments is a common limitation in research examining cognitive impairments linked to FASD (Korkman et al., 2003). Further research examining the impact of psychosocial factors on executive function development in children with FASD is required.

There was not sufficient detailed information available on the frequency, quantity, and gestational timing of maternal alcohol use to conduct a more thorough analysis of the relationship between PAE and executive function. In addition, at least six (9.7%) participants in the control group had a documented history of minimal prenatal alcohol exposure (defined as equal or less than one drink per week on average and never more than two drinks on any occasion). The relationship between minimal PAE and neurodevelopmental outcomes is not yet well understood (Bandoli et al., 2023), and it is possible that minimal alcohol exposure may have impacted the performance of the control group, minimising differences between the two groups.

A large percentage of mothers smoked during the index pregnancy, this being significantly more prevalent in the FASD group (79.2%) than in the control group (30.6%). A growing body of evidence suggests that in addition to issues associated with low birth weight and preterm birth, smoking during pregnancy may also be harmful to cognitive development (see Clifford et al., 2012 for review). However, the potential impact of tobacco exposure during pregnancy was not controlled for.

The cross-cultural validity of the neuropsychological tests and questionnaires used in this study has not yet been adequately assessed. Despite the proliferation of publications addressing issues of cross-cultural neuropsychology over the past three decades, the majority

of neuropsychological tests remain available only in English (Olson & Jacobson, 2015). In this study, all participants spoke Afrikaans as their first language, which necessitated the translation of the questionnaires, test instructions, and verbally mediated test material into Afrikaans. The translation process may have affected the validity of the tests and the questionnaires. Moreover, various factors aside from brain-behaviour relationships are known to impact performance on neuropsychological assessment tools. This includes factors such as the quality and quantity of education, SES, and the degree of Westernisation (Ferrett, Carey, et al., 2014; Kusi-Mensah et al., 2022; Olson & Jacobson, 2015; Shuttleworth-Edwards, 2016). Low scores on tests normed on samples from HMICs (such as the U.S.) pose the risk of false positive diagnoses of cognitive impairments in individuals from LMICs, such as South Africa, particularly in low-SES communities (Ferrett, Carey, et al., 2014; Shuttleworth-Edwards, 2016). A recent systematic review found very limited evidence for the reliability and validity (structural, cross-cultural, and construct) for the most commonly used tests of executive function in LMICs (Kusi-Mensah et al., 2022), and there is an urgent need for the adaptation and standardisation of neuropsychological tests such as the D-KEFS and behavioural measures, such as the BRIEF, for South African children and adolescents. Executive function tests are typically designed in such a way that the type of activity is familiar, and the test-taker is capable of deducing expectations but is faced with unfamiliarity that necessitates the development of innovative strategies to achieve success. These tasks may resemble activities involving playing card games or solving logical puzzles, with their prevalence and familiarity varying across different cultural contexts. This makes translating and adapting executive function tests very challenging (Judd et al., 2023). One possible solution is for future studies to consider adapting tasks that have greater universal applicability and ecological validity, such as cooking tasks (Kusi-Mensah et al., 2022).

Closing statement

Despite the shortcomings outlined above, the current study has many strengths, including its comparison between alcohol-exposed and typically developing adolescents from a low-SES community from an LMIC. This is one of the first longitudinal studies to examine the development of executive function in children with a history of PAE. It is also one of the few studies that employed both neuropsychological and behavioural measures to examine executive function in individuals with FASD, in line with best-practice recommendations for the assessment of this complex area of cognition (Gioia et al., 2008). By obtaining both parent and teacher ratings of everyday executive function, the present study was able to extend previous research in this area.

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Appendix

Consent and Assent form for the parents and participants in the study: "A Multisite Neurobehavioral Assessment of Fetal Alcohol Spectrum Disorders"

Collaborative Initiative on FASD Project

Department of Psychiatry and Mental Health

June 2009

CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

An analysis of the learning process and behaviour in South African and American children with Fetal Alcohol Spectrum Disorders (FASD)

Dear Parent

Dr Colleen Adnams and her team from the University of Cape Town are busy conducting a research project. The goal of the project is to understand the development and learning process of schoolchildren who have been exposed to alcohol before birth.

This research will be conducted in Wellington as well as in certain states in the United States of America (USA). This study is funded by the government of the USA's National Institute on Alcohol Abuse and Alcoholism (NIAAA). One Thousand children between 8 and 16 years of age and their families will be involved in this study. All these families will come from Wellington as well as the certain states in the USA. For the research outcomes to be comparable there are children in this study that have not been exposed to alcohol before birth.

PROCEDURE

If you decide to participate in this study, and give your consent for your child to participate in this study, the following shall happen:

Your child will be evaluated on a range of tests that examine his/her aptitude in a range of areas. You, your child, and your child's teacher will be asked to fill out a number of

questionnaires about your child's behaviour and emotions. You may also be asked to take part in face-to-face interview. You and your child can decline to answer a question or withdraw from the study at any time.

The research will begin in June 2009 and run until 2012. The testing of your child will take place during school hours in our research office in Wellington. Your child will be transported by a reliable member of the research team.

Information about the tests and the progress your child has made in this research will shared with you, your child and your child's school.

VIDEO FILMING AND AUDIO-RECORDING

We also ask your permission to film your child during the testing. The identity of your child will be maintained. Only a study number assigned to your child will be used in the research. You can decline the filming and recording of your child.

RISKS AND ACCIDENTS

We draw your attention to the fact that if you or your child is involved in an accident while you/your child are participating in the study, the study will cover the costs through insurance.

BENEFITS

There may or may not be direct benefits to you or your child by participating in this study. We hope that what is learned through this study will make people more aware of the interventions needed for children that have been exposed to alcohol before birth.

CONFIDENTIALITY

Any information that you give during this study will be reliably handled. Your name will not be used in any publications about this study.

COST OF THE STUDY

There will be no cost incurred to you connected to this study. You will not be accountable for any of the costs of the tests or procedures connected with this research.

PARTICIPATION

Your participation in this study completely voluntary. You have the right to not take part in

the study or to withdraw from the study at any time.

QUESTIONS

If you have any questions in connection with this study, you can contact the principal investigator or project coordinator at the University of Cape Town.

Dr Colleen Adnams - UCT Tel. 021 404-2173

Project Coordinator UCT Tel. 021 404 5385

If you have any ethical questions in connection with the project you can contact the University of Cape Town Research Ethics Committee:

Dr Mark Blockman, Head: UCT Ethics Committee Tel 021 406-6942.

CONSENT

If your child is older than seven years, he/she must also give his/her assent to partake in this study and the rest of this form must be completed. If your child is younger than seven years this part of the form does not need to be completed.

_____

Childs' name (Print)

_____ _____

Childs' signature Date

You, as parent, give permission for your child to participate in this study. Your signature hereunder shows that you and your child have decided to participate in this study and that you have read the above information or that it was read to you.

I have read the above information (or have had it read to me). I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. By signing this consent form, I give consent for myself and my child's participation in this study.

_____

Childs' name (type or print)

_____

Parent/Guardians' Name

_____ _____

Parent/Guardians' Signature Date

Address _____Telephone number_____

_____

Witness **if one is present** (Type or print)

_____ _____

Signature of Witness Date

If a researcher has explained the information:

I have explained all information and answered all questions related to this research project to the child and his/her guardian. I believe that he/she has understood the information in this consent form and has voluntarily decided to participate in the study.

_____ _____

Name and signature of research team member Date