

**A NEEDS ANALYSIS OF GESTURE USE BY CHILDREN WITH FETAL
ALCOHOL SYNDROME DURING MATHEMATICS INSTRUCTION**

by

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I declare that A NEEDS ANALYSIS OF GESTURE USE BY CHILDREN WITH FETAL ALCOHOL SYNDROME DURING MATHEMATICS INSTRUCTION is my own work and that all of the sources I have used or quoted have been indicated and acknowledged by of means of complete references.

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DATE

DEDICATION

This study is dedicated to the children with Fetal Alcohol Syndrome who overcome their challenges on a daily basis. Your courage gives hope.

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ABSTRACT

The effects from prenatal alcohol exposure have been found to cause a range of congenital physical and cognitive abnormalities (Chasnoff, Wells, Telford, Schmidt, & Messer, 2010; Kable & Coles, 2004a). The neurological impairments associated with the effects from prenatal alcohol exposure often cause learning problems, most notably in mathematics (Kable & Coles, 2004a; Howell et al., 2006). Studies have indicated that when provided instructional interventions in mathematics, children affected by prenatal alcohol exposure made gains in learning. However, the studies did not provide specifics as to how children with FAS construct the understanding of a skill or concept (Kable, Coles, & Taddeo, 2007; Coles, Kable, & Taddeo, 2009).

This study contributes to the literature by examining how children affected by prenatal alcohol exposure learn the concept of equivalence through their use of gestures in contrast to their learning outcomes. Previous studies have shown that children's use of gestures while learning mathematics assist with the integration of verbal and visual stimuli, support concept formation, and facilitate flexible encoding of problems (Goldin-Meadow, Cook, & Mitchell, 2009; McNeil & Alibali, 2004).

The results from this study indicated that children in the Alcohol Exposed group showed little to no learning after the intervention as compared to a control group matched by age and IQ. The study showed that children affected by prenatal alcohol exposure used fewer conceptual gestures while learning equivalence as compared to a control group. According to the gesture analysis, the children in the Alcohol Exposed group mentally represented the concept of equivalence as a series of isolated steps or procedures. The procedural representation was not transitioned into a flexible conceptual format and applied to solve different problem types accurately (McNeil & Alibali, 2004).

Future studies need to investigate whether teaching children affected by prenatal alcohol exposure to gesture during mathematics instruction would be effective to increase concept formation, accurate encoding, and learning mathematics.

Keywords:

Fetal Alcohol Syndrome, prenatal alcohol exposure, gestures, mathematics learning, mathematics disorder, equivalence, and concept formation

ACRONYMS AND ABBREVIATIONS

Alcohol Related Birth Defects (ARBD)
Alcohol Related Neurodevelopmental Disorders (ARND)
Attention Deficit Hyperactivity Disorder (ADHD)
Beery-Buktenica Developmental Test of Visual Motor Integration (VMI)
California Verbal Learning Test, Children's Version (CVLT-C)
Centers for Disease Control and Prevention (CDC)
Diffusion Tensor Imaging (DTI)
Fetal Alcohol Effects (FAE)
Fetal Alcohol Spectrum Disorders (FASD)
Fetal Alcohol Syndrome (FAS)
Intellectual Quotient (IQ)
Institute of Medicine (IOM)
Magnetic Resonance Imaging (MRI)
Math Interactive Learning Experience (MILE)
Partial Fetal Alcohol Syndrome (pFAS)
Representational Redescription Model (RR)
Standard Deviation (SD)
Standard Error of Measurement (SEM)
Standard Score (SS)
Trends in International Mathematics and Science Study (TIMMSS)
Wide Range Assessment of Memory and Learning (WRMAL)

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CHAPTER ONE

ORIENTATION AND OVERVIEW

1.1 INTRODUCTION

“Sometimes the questions are complicated but the answers are simple” - Dr. Seuss

It is estimated that as many as one out of one hundred children in the United States and South Africa are affected by prenatal alcohol exposure (Olsen et al., 2009). The effects from prenatal alcohol exposure are associated with congenital physical and neurological abnormalities that cause a range of developmental disabilities and learning difficulties (Jones & Smith, 1973; Bertrand et al., 2004). The prevalence of Fetal Alcohol Spectrum Disorders (FASD) including the clinical diagnoses of Fetal Alcohol Syndrome (FAS) and Partial Fetal Alcohol Syndrome (pFAS) is similar to other developmental disorders such as Fragile X, and Spina Bifida (Bertrand et al., 2004; Shin et al., 2010). Though the pervasiveness of FASD is comparable to other developmental disabilities, minimal research has been conducted into specific academic deficits and interventions for children affected by prenatal alcohol exposure (Bertrand, 2009).

The neurological impairments associated with the effects from prenatal alcohol exposure may cause secondary learning disabilities (Howell, Lynch, Platzman, Smith, & Coles, 2006; Kable & Coles, 2004a). Deficient encoding of visual information, decreased processing speed, and weaknesses retaining information in working memory are related to the effects from gestational alcohol exposure (Mattson, Calareco, & Lang, 2006; Howell et al., 2006; Burden, Jacobson, Sokol, & Jacobson, 2005; Willford, Richardson, Leech, & Day, 2004; Jacobson & Jacobson, 2002; Matteson & Roebuck, 2002; Koditkuwakku, Kalberg, & May, 2001; Uecker & Nadel, 1996). Often children affected by prenatal alcohol exposure exhibit deficits in one or more of these areas that cause problems learning mathematics (Howell, et al., 2006). Yet, children with FAS are able to make gains in their overall mathematic achievement scores after receiving instructional interventions (Kable, Coles, & Taddeo, 2007; Coles, Kable, & Taddeo, 2009; Bertrand, 2009). The studies show that children with FAS respond to interventions but they do not indicate how the children constructed understanding to change their learning.

Gestures are an integral aspect of communication and thought (Streeck, 2009). Gestures assist with integration of spatial information into a format that can be represented in language (Hostetter, Alibali, & Kita, 2007; Kita, 2000; Streeck, 2009). Studies have shown that children use gestures to sustain attention while counting object and to maintain information in working memory to compute problems (Cook, Mitchell, & Goldin-Meadow, 2008; Carlson, Avraamides, Cary, & Strasberg, 2007; Flevares & Perry, 2001).

Observing children's gestures provides insight as to how children formulate a concept or learn strategies to solve a problem. Perry, Breckinridge Church, and Goldin-Meadow (1988) conducted a study investigating children's coordination of gestures and speech while learning the concept of equivalence. The authors suggested that children who present the same message in gesture and speech exhibit a stable understanding of a concept. Transitions in thoughts are indicated when gestures and speech do not contain the same message. Perry et al. inferred that mismatched messages presented in gesture and speech signified that children activated more than one idea. Once knowledge has been transformed and stabilized, children's gestures and speech again present a similar message. The observation of children's gestures provides a glimpse into transitions of thoughts.

Studies investigating gesture use by children with developmental disabilities, such as Williams syndrome and Down syndrome, have shown the use of gestures support concept formation, organizing thoughts, and word retrieval (Caselli, Vicari, Logobardi, Lami, Pizzoli, & Stella, 1998; Bello, Capirci, & Volterra, 2004; Evans, Alibali, & McNeil, 2001). Though studies have examined the coordinated use of speech and gestures by children with Williams syndrome, Down syndrome and language disorders, little to no research has been conducted into the use of gestures by children affected by prenatal alcohol exposure (Millians, Coles, & Michener, 2007).

This study examines how children with FAS learn a concept in a noted academic area of weakness. Specifically, the study investigates whether the information gathered from the observations of coordinate speech and gestures give insight as to how children with FAS construct knowledge during the learning process. This information may enable teachers to intervene to prevent inaccuracies in learning.

Chapter one provides an overview of this dissertation. The chapter presents the study's paradigm, the statement of the problem, the research questions and hypotheses, and the

delimitations of the study. The terms used throughout the study are defined in this chapter. Also, the chapter also provides a summary of the study's theoretical foundations, procedures to collect the data, and the methods used to analyze the information. The chapter concludes with an outline of subsequent chapters.

1.2 STUDY PARADIGM

As will be discussed later in this chapter, the aims of the study are to gather information about how children with FAS construct understanding of a concept in mathematics, an identified area of academic weakness, to inquire whether children with FAS use of gestures facilitate learning, and to gain insight into ways to develop effective instructional interventions (Howell et al., 2006; Kable & Coles, 2004a).

To investigate learning and the use of gestures by children with FAS, an empirical approach that is derived from a positivist paradigm is selected as the basis for the study (Breedo, 2006; Kelly, 2006). Empirical studies rely upon the generation of hypotheses to guide the investigation, the use of direct or indirect observations to gather data, and the application of statistical methods to analyze the data (Kelly, 2006). Empirical studies based upon a positivist paradigm implement controls to limit confounding factors in order to determine the associations among events or situations as inferred through the statistical analysis (Kelly, 2006). Given the experimental designs and level of controls, the findings from empirical studies are considered to be valid representations of the constructs examined (Mertens & McLaughlin, 2004).

The next section presents the problem that is to be examined in this study.

1.3 STATEMENT OF THE PROBLEM

Children with FAS exhibit compromised cognitive functioning and deficits in mathematics (Kable et al., 2007, Kable & Coles, 2004a). However, there is limited research regarding how children with FAS construct their understanding of mathematical concepts. Given the cognitive impairments associated with prenatal alcohol exposure, it is feasible for children with FAS to exhibit a minimal use of representative gestures while learning mathematics (Kable & Coles,

2004a; Kita, 2000; McNeill, 1992; Alibali & Goldin-Meadow, 1993). A minimal use of coordinated speech and gesture may limit integration of spatio-motoric and linguistic information to form and apply new concepts to solve problems may contribute to the difficulties experienced by many children with FAS learning mathematics (Alibali, 2005; Kita, 2000; Streeck, 2009; Kable et al., 2007; Rasmussen & Bizanz, 2009).

This study investigates whether children affected by prenatal alcohol exposure use coordinated gesture and speech to facilitate learning the mathematical concept of equivalence, a rudimentary mathematical concept (Knuth, Stephens, McNeil, & Alibali, 2006; Seo & Ginsburg, 2003). The findings may provide information about the viability of gesture analysis to assess how child with FAS construct the understanding of a specific mathematical concept. The information gathered from the study may suggest ways to devise instructional interventions that can be implemented during teaching to prevent learning problems (Rasmussen & Bisanz, 2009; Bertrand, 2009; Kable et al., 2007).

The aims of the study are presented in the next section.

1.4 AIMS OF THE STUDY

The aims of the study are threefold and are discussed below.

1.4.1 Aim One

Brain imagining studies suggest that abnormalities in the corpus callosum and in the parietal region are associated with the effects from prenatal alcohol exposure. Also, brain imaging studies have shown the loss of white matter integrity is linked to the effects from gestational alcohol exposure (Wozniak & Muetzel, 2011; Santhanam, Li, Coles, & Lynch, 2010). Abnormalities of the corpus callosum and white matter degradation are associated with problems integrating verbal and visual information and decreased processing speed (Wozniak & Muetzel, 2011). Furthermore, studies have shown that abnormalities to the parietal region of the brain caused by prenatal alcohol exposure impair the abilities to determine number magnitude and to estimate amounts (Meintjes et al., 2010; Jacobson; Jacobson, Dodge, Burden, Klorman, & Jacobson, 2011).

Due to the cognitive impairments associated with prenatal alcohol exposure, children with FAS experience problems with learning, especially in mathematics. Studies have shown that children with FAS demonstrate lower scores on mathematical achievement tests when compared to peers matched by age and intellectual abilities (Howell et al., 2006).

Though studies have shown that children with FAS exhibit weaknesses in numerical processing as a result of the compromises to cognitive processes, limited research has investigated how children with FAS construct their understanding of mathematics (Bertrand, 2009; Kable et al., 2007). Therefore, the first aim of this study is to investigate how children affected by prenatal alcohol exposure construct their understanding of a mathematical concept. Investigation into how children with FAS construct knowledge of a mathematical concept is conducted through the systematic observation of their gesture use.

1.4.2 Aim Two

Research has shown that children use gestures to integrate verbal and visuo-spatial information to form concepts (Alibali & Goldin-Meadow, 1993; Perry et al., 1988; Kita, 2000). Studies indicate that observing children's use of gestures provides insight into their level of understanding a mathematical concept and their readiness for instruction (Alibali & Goldin-Meadow, 1993; Perry et al., 1998). Also, studies have shown that children with and without developmental disabilities use gestures to support different functions that include expressing ideas and to facilitate integration of information (Caselli et al., 1998; Bello, Capirci, & Volterra, 2004). However, research has not identified a consistent pattern of gesture use among children with genetic disorders or developmental disabilities, including children affected by prenatal alcohol exposure (Millians et al., 2007).

Based upon a review of the literature, there is limited research into the use of gestures by children affected by prenatal alcohol exposure (Millians et al., 2007). Therefore, the second aim of this study is to investigate whether gestures used by children with FAS are influential in their learning and communicating about their understanding of a mathematical concept.

1.4.3 Aim Three

Studies have shown that children affected by prenatal alcohol exposure exhibit deficits in mathematics (Koditkuwakku, 2009). Research has shown that children are able to make gains in mathematics when provided interventions that address the underlying learning deficit (Kable et al. 2007; Coles, et al., 2009). However, the studies did not provide information as to how children with FAS transition information to create new knowledge and to support learning (Karmiloff-Smith, 1992; Kable et al., 2007). Therefore, the third aim of this study is to contribute to the understanding of the cognitive processes and the difficulties in mathematics experienced by children affected by prenatal alcohol exposure. The information from the study is to contribute to the development of instructional interventions needed to address the mathematical deficits in a population that has had minimal consideration in the literature (Bertrand, 2009; Koditkuwakku, 2009).

The aims of the study are explored through the research questions and hypotheses that are discussed in the next sections.

1.5 STUDY QUESTIONS

The primary question, the two sub-questions, and the supportive rationale are discussed in this section.

1.5.1 Primary question

Often children affected by prenatal alcohol exposure demonstrated deficits in numerical processing and low scores on mathematical achievement tests (Jacobson et al., 2011; Howell et al., 2006; Santhanam, et al., 2010). Based upon the literature, the primary study question considers whether children with FAS may show a difference in learning the concept of equivalence as compared to children whose development was reported to be unremarkable. Based upon the noted deficits in mathematics, the primary question inquired:

- Will children affected by prenatal alcohol exposure demonstrate a poorer understanding of equivalence as compared to children without a clinical diagnosis?

1.5.2 Two sub-questions

During the learning process, children are asked to explain their understanding of a concept. Studies have shown that children with and without developmental disabilities use gestures to explain their ideas and to facilitate the learning of a mathematical concept (Caselli et al., 1998; Evans, Alibali, & McNeil, 2001; Alibali & Goldin-Meadow, 1993; Perry et al., 1988; Kita, 2000). Studies have indicated that children with FAS exhibit difficulties in mathematics but make academic gains when provided interventions such as those presented through the Math Interactive Learning Experience (MILE) program (Kable et al., 2007; Coles et al., 2009; Bertrand, 2009). However, the research does not examine the specific changes in how children construct understanding in mathematics. The two sub-questions for this study inquire whether children with FAS use gestures to support the learning of the mathematical concept of equivalence in order to investigate how they learn. The questions are stated below.

- Do children affected by prenatal alcohol exposure use fewer conceptual gestures to explain their understanding of equivalence as compared to children without a clinical diagnosis?
- Will there be a correlation between the types of gestures used and the outcomes on the mathematics post-test?

The hypotheses derived from the study's questions are presented in the next section.

1.6 HYPOTHESES

Based upon the primary question and the two sub-questions, three hypotheses are examined in this study and stated below.

- (H₁) Children in the Alcohol Exposed group will have lower scores on the pre-test and the post-test than the Non-exposed group. Previous research has noted that children with FAS exhibit processing deficits that impede mathematics learning (Burden, Jacobson, & Jacobson, 2005; Howell et al., 2006). The use of a pre-test and post-test design is to assess the children's overall learning as shown by a traditional paper-and-pencil task.

- (H₂) Children in the Alcohol Exposed group will exhibit a lower number of conceptual gestures as compared to the Non-exposed group. Given the deficits in encoding, processing, and integrating verbal and visual information, it is likely that children with prenatal alcohol exposure will use fewer conceptual gestures to support concept and to explain their ideas (Hostetter, Alibali, & Kita, 2007; Kita, 2000; Willford et al., 2004; Mattson & Roebuck, 2002).
- (H₃) Children who demonstrate fewer conceptual gestures will score lower on the mathematics post-test. This hypothesis is based upon prior research that suggests that a limited use of gesture to integrate information would indicate a static mind set or weak conceptual understanding of a mathematical concept (Alibali & Goldin-Meadow, 1993; Perry et al., 1988; Karmiloff-Smith, 1992).

1.6.1 Exploratory analysis

Other factors, such as age and intellectual function, may contribute to the use of gestures while learning a mathematical concept. Studies have suggested that decreases in the use of gestures occur in relation to increases in age and linguistic knowledge (Stefaninis, Bello, Caselli, Iverson, & Volterra, 2009). To investigate whether age and/or cognitive abilities are associated with gesturing and learning, two exploratory questions are examined:

- Are there relationships between age, IQ, and the use of conceptual, operational, and total number of gestures?
- Are age, IQ, and the use of conceptual gestures associated and predictive of children's learning of equivalence?

The possible factors that may limit generalization of the findings from this study are presented in the next section.

1.7 DELIMITATIONS

There are factors that restrict the generalization of the findings to a larger population of children with FAS.

- 1) The sample for this exploratory study is small and targets a specific age range. A study with a larger sample size needs to be conducted to determine if gesture use is an effective method to assess how children affected by prenatal alcohol exposure learn mathematics across grade and age levels.
- 2) It is possible that the findings from the study may reflect global intellectual deficits that are unrelated to the effects from prenatal alcohol exposure.
- 3) The participants in the study are between the ages of 8.0 and 12.9 years old. However, one participant turned 13.0 before completing the post-test. Given the age span of the participants, the results may reflect age-related differences in the participants' learning of equivalence.
- 4) It is possible that the results may be influenced by variations in the quality of mathematics instruction received by the participants. For example, over-exposure to common arithmetic problem formats (e.g. $5 + 3 = 8$) may interfere with children's awareness of changes in problem features when presented novel problems (McNeil & Alibali, 2004; McNeil & Alibali, 2005; McNeil, Grandau, Knuth, Alibali, Stephens, Hattikudur, & Krill, 2006).
- 5) The study investigates the use of gesture to assess the learning of equivalence in children and may not be applicable to other mathematic topics, such as learning about fractions (Donovan, Bransford, et al., 2004).
- 6) The study implements a quasi-experimental design with the participants grouped according to their diagnosis of FAS, pFAS, or no clinical diagnosis. The results may reflect bias due to the assignment of the groups by diagnosis and not randomly assigned to an intervention group (Shadish & Luellen, 2006).

Though there are constraints to this study, the findings may provide information about processing patterns that affect mathematics understanding in children with an alcohol related diagnosis. The outcomes may provide information about the usefulness of gesture analysis to assess mathematics learning in children with an alcohol related diagnosis. Information gathered from this study may pinpoint areas for future research exploring mathematical interventions for children with FAS.

1.8 DEFINITION OF TERMS

The terms used throughout this dissertation include Fetal Alcohol Spectrum Disorders (FASD), Fetal Alcohol Syndrome (FAS), Partial Fetal Alcohol Syndrome (pFAS), working memory and encoding, visual-spatial processing, mathematic concept of equivalence, mathematic procedure and operation, mathematic equation, gestures, conceptual gestures, and operational gestures are defined in this section.

1.8.1 Fetal alcohol spectrum disorders, fetal alcohol syndrome, and partial fetal alcohol syndrome

Multiple terms are used to describe the effects from prenatal alcohol exposure (Bertrand, Floyd, & Weber, 2005). Fetal Alcohol Spectrum Disorders (FASD) is a general term used to encompass the range of effects associated with prenatal alcohol exposure (Bertrand, Floyd, & Weber, 2005). FASD incorporates the medical diagnosis of Fetal Alcohol Syndrome (FAS) and Partial Fetal Alcohol Syndrome (pFAS). It is important to note that “FASD is not a diagnostic category and should be used only when referring to the collection of diagnostic terms resulting from prenatal alcohol exposure” (Bertrand, Floyd, & Weber, 2005, p. 2).

Fetal Alcohol Syndrome (FAS) and Partial Fetal Alcohol Syndrome (pFAS) indicate that individuals have met the criteria to receive a medical diagnosis. A diagnosis of Fetal Alcohol Syndrome (FAS) “is given if evidence of alcohol related dysmorphia, growth deficiencies currently or at birth, and cognitive impairments not related to post-natal injury or other medical conditions are present” (Bertrand et al., 2004, p. vii;). A diagnosis of FAS may be given without documentation of maternal alcohol use during pregnancy if significant alcohol related facial

dysmorphia, growth deficiencies, and damage to the central nervous system are present and cannot be explained by other medical causes (Bertrand et al., 2004).

To receive a diagnosis of Partial Fetal Alcohol Syndrome (pFAS), individuals are required to have documented evidence of prenatal alcohol exposure, and dysmorphia, and exhibit either physical or neurological impairments that cannot be explained by other medical conditions (Kable & Coles, 2004a).

1.8.2 Working memory, encoding, and processing

Children affected by prenatal alcohol exposure may exhibit impairments with efficient intake and processing of information needed to complete tasks. Research has suggested that weaknesses with encoding impede the manipulation of information in the working memory system (Burden, Jacobson, & Jacobson, 2005; Kodituwakku et al., 2001).

Working memory is defined as the mental workplace where information is manipulated and maintained for additional encoding and processing (Baddeley, 2002; Gathercole, Pickering, Abridge, & Wearing, 2004).

Encoding is the representation and transformation of information to be used for processing or storage in memory (Willford, et al., 2004; Mattson & Roebuck, 2002; Mattson, Calarco, & Lang, 2006).

Processing refers to the speed to attend, encode, manipulate, and respond to presented stimuli (Burden, Jacobson, & Jacobson, 2005).

1.8.3 Visual-spatial processing

The cognitive effects from prenatal alcohol exposure include weaknesses with processing visual-spatial information (Uecker & Nadel, 1996). Visual-spatial processing is defined as the ability to manipulate mental representations for additional processing, use, or storage in memory (Cornoldi & Vecchi, 2003).

1.8.4 Mathematical concept of equivalence

Mathematic concepts are defined as the foundational ideas needed to perform operations, to select procedures, and to apply strategies. Concepts provide the scaffolding to learn complex mathematics (Kilpatrick, Swafford, & Findell, 2001). Equivalence is an underlying concept needed for algebraic thinking and advanced mathematics. Equivalence, as defined in this study, means the “the same as” and indicates a similar relationship between numbers separated by the equal sign (Seo & Ginsburg, 2003, p.161; Kieran, 1981; Knuth, Stephens, McNeil, & Alibali, 2006).

1.8.5 Mathematical equation and procedure

A mathematical equation is defined as “any mathematical statement that uses the equal sign to indicate that two mathematical expressions are (or defined to be) equivalent” (McNeil & Alibali, 2005, p. 883; Nichols & Schwartz, 1999).

A mathematical procedure is defined as the sequence of steps used to solve problems (Rittle-Johnson, Siegler, & Alibali, 2001; Rittle-Johnson & Alibali, 1999). A mathematical operation is the “act upon one or more numbers” to produce an answer (Nichols & Schwartz, 1999, p. 266; McNeil & Alibali, 2005).

1.8.6 Gestures, conceptual gestures, and operational gestures

The gestures considered for this study are hand, arm, and shoulder movements that co-occur with speech to express information. Gestures can be classified according to the type of information they present. For example, representative gestures are movements used to indicate an event, an idea, or an object closely related to the message conveyed in speech. For example, a person may lower a hand to describe climbing down a ladder (McNeill, 1992; Alibali, Kita, & Young, 2000; Kita, 2000).

This study will analyze children’s use of conceptual gestures and operational gestures to explain equivalence. A conceptual gesture of equivalence is defined as hand and/or arm movements that represent the similar relationship between numbers on each side of the equals sign (McNeil & Alibali, 2005; Alibali, Garber, & Goldin-Meadow, 1993).

An operational gesture is defined as hand and/or arm movements that reflect the action and/or the procedure used to change a number without representing the understanding of equivalence. For example, children pointing to each mathematical equation and stopping after the equals sign to give an answer does not indicate that the values on each side of the equal sign are the same or equivalent (Alibali & Meadow, 1993; McNeil & Alibali, 2005).

The next section provides a brief review of the literature.

1.9 LITERATURE REVIEW

A brief summary of the literature that is the basis for this study is presented in this section. A comprehensive review of the literature on FAS and gestures are found in chapters two and three of this dissertation.

1.9.1 Fetal alcohol syndrome

Jones and Smith (1973) conceived the term Fetal Alcohol Syndrome (FAS) in the early 1970s to define the effects caused by prenatal alcohol exposure. In the mid-1990s the Institute of Medicine (IOM) outlined the diagnostic criteria to assist medical professionals in accurately diagnosing the effects caused by gestational alcohol exposure (Stratton, Howe, & Battaglia, 1996). In 2004, the Centers for Disease Control and Prevention (CDC) in collaboration with the National Center on Birth Defects and Developmental Disabilities, the Department of Health and Human Services, and the National Task Force on Fetal Alcohol Syndrome and Fetal Alcohol Effect updated and published guidelines for referral and diagnosis.

The CDC estimated that FAS occurs between 0.2 to 1.5 cases per 1,000 births in the United States (Bertrand et al., 2004, p. 2). In South Africa, the prevalence of Fetal Alcohol Spectrum Disorders (FASD) and FAS, pFAS, as well as children affected by prenatal alcohol exposure but who do not exhibit physical features is estimated to be approximately 72.3 out of 1,000 births (May et al., 2009, p.188). The prevalence rate of FAS in the United States and in South Africa is comparable to the rates of more commonly known developmental disabilities such as Spina Bifida or Fragile X (Bertrand, Floyd, & Weber, 2005, p. 2). Shin et al. (2010) reported the approximated prevalence rate of children and adolescents in ten regions of the United States

including Georgia, Arkansas, California, Colorado, Iowa, New York, North Carolina, Utah, Oklahoma, and Texas, to be 3.1 cases per 10,000 children (p.274). Studies have suggested that the estimated prevalence of males with Fragile X to be 1 in 4,000 and the estimated prevalence of females to be 1 in 5,000 - 8,000 (Hill, Archibald, Cohen, & Metcalfe, 2010, p. 396). Again, the prevalence rate of children with FAS and FASD is similar to or higher than the rate of children with other developmental disabilities yet there is minimal consideration in the literature regarding interventions for children affected by prenatal alcohol exposure (Bertrand et al., 2004; Hill et al., 2010; Bertrand, 2009).

The effects from prenatal alcohol exposure vary according to the individual. This is due to the amount and duration of alcohol consumed by the biological mother during pregnancy (Kable & Coles, 2004a). Also, the age and prior number of the pregnancies of the biological mother contribute to the severity of the neurological and physical abnormalities associated with the effects from gestational alcohol exposure (Kable & Coles, 2004a; Bertrand et al., 2004).

The cognitive impairments associated with the effects from prenatal alcohol exposure interfere with learning mathematics. Studies have indicated that children and adolescents with FAS exhibit deficits in mathematics as shown by their performance on achievement tests (Howell et al., 2006; Coles, Kable, Drews-Botsch, & Falek, 2000). Kopera-Frye, Dehaene, and Streissguth (1996) found that students with FAS showed weaknesses in number estimation as compared to a control group of non-exposed peers. Coles, Kable, Drews-Botsch, and Falek (2000) noted specific deficits in early mathematics skills related to understanding number concepts in a heterogeneous sample of preschool children. Studies have suggested that children with FAS struggle to retain and to manipulate information to complete an arithmetic task (Burden, Jacobson, Sokol, & Jacobson, 2005). Also, the noted deficits in processing visual-spatial information and encoding interfere with mathematics, especially in the areas of geometry, solving word problems, interpreting symbols, and estimation (Geary, 2004; Hegarty & Kozgevnikov, 1999). Chapter two of the dissertation discusses in depth the diagnostic criteria, the prevalence, and the range of cognitive and learning impairments associated with the effects from prenatal alcohol exposure.

Research has suggested that children use gestures to assist with concept formation and integration of information especially in mathematics. The next section discusses how gestures are used to support learning mathematics.

1.9.2 Gestures and learning

Gestures are defined as visible body actions that are a component of an utterance and are used to convey information to a listener or to support the processing of spatial and linguistic information (Kendon, 2004; McNeill, 1992; Kita, 2000). These movements co-occur with speech and are used to integrate information, to emphasize relevant information, and to draw attention to specific locations (Langton & Bruce, 2000; Kita, 2000).

Often in a classroom, instructors and students use gestures during mathematics instruction to convey visual-spatial information that cannot easily be verbalized (Goldin-Meadow, Kim, & Singer, 1999; Alibali, 2005). During instruction, teachers and children use gestures to link verbalizations with the mental representations to express ideas (Goldin-Meadow, 1999; Goldin-Meadow, Kim, & Singer, 1999; Breckinridge Church & Goldin-Meadow, 1986; Goldin-Meadow, 2000).

Children's use of gestures reveal thought processes that are not yet coded into language. Goldin-Meadow, Alibali, and Breckinridge Church (1993) suggested that co-occurrence of gesture and speech presented "an observable, and interpretable, index of the child's conceptual knowledge, and thus provide a mechanism by which adults can calibrate their input to a child's current level of understanding" (p.295). Attention to children's gesturing, specifically gesture-speech mismatches that denote transitions in children's conceptual understanding, provide insight into the readiness for instruction (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007; Perry et al., 1988; Alibali & Goldin-Meadow, 1993).

Children's use of gestures varies according to difference in spatial abilities, the cognitive demands of an activity, and their knowledge of a topic (Alibali, 2005; Erlich, Levine, & Goldin-Meadow, 2006; Wagner, Nusbaum, & Goldin-Meadow, 2004). Children with developmental disabilities are found to use gestures to support different cognitive functions. The next section discusses the use of gestures by children with developmental disabilities.

1.9.3 Gestures and children with developmental disabilities

The use of gestures has been examined in children with developmental disabilities such as Williams syndrome and Down syndrome. Studies have shown the gesture use vary according to

the cognitive impairments associated with the different development disabilities (Bello, Caprici, & Volterra, 2004; Caselli et al., 1998; Stefaninis, Caselli, & Volterra, 2007).

Gesture use has been investigated in children with Williams syndrome, a genetic disorder caused by a microdeletion on chromosome 7 at 7q11.23 (Laing et al., 2002; Vicari, Bellucci, & Carlesimo, 2003). The chromosomal deletion causes an uneven developmental profile and in many cases mental retardation. Also, weaknesses in visual-spatial processing, inefficient word retrieval, and difficulties with cognitive planning are associated with the effects from Williams syndrome (Liang et al., 2002; Jarrold, Baddeley, & Hewes, 1998). The cognitive impairments associated with Williams syndrome are similar to those attributed to the effects from prenatal alcohol exposure. For example, as observed in children with FAS, often children with Williams syndrome display a relative strength in naming vocabulary in contrast to their understanding of abstract linguistic concepts (Bello et al., 2004; Kable & Coles, 2004a).

In a study exploring lexical organization, word retrieval, and naming accuracy accompanied by the use of gesture in children with Williams syndrome, Bello, Caprici, and Volterra (2004) found that children with Williams syndrome and age-matched peers have similar lexical abilities. Their findings showed that children with Williams syndrome were slower at retrieving object names as compared to the unimpaired control group. Additionally, Bello et al. discovered that children with Williams syndrome used gestures more than the control group to facilitate word retrieval, to recall of spatial information, and to access categorical information.

Children with Down syndrome exhibit a different pattern of gesturing as compared to children with Williams syndrome. Down syndrome is a genetic disorder caused by trisomy on chromosome 21. Studies examining gesture use in children with Down syndrome have found an increase of gesturing to express ideas as compared to typically developing children. The results from a study conducted by Caselli, Vicari, Longobardi, Lami, Pizzoli, and Stella (1998) indicated that children with Down syndrome showed an increase in their gesture use when cognitive demands interfered with their abilities to verbalize their thoughts. Casselli et al. suggested that children with Down syndrome increased their gesturing when conveying symbolic information, actions, and imaginative or transformative messages. The authors concluded that the increase of gesture use to facilitate verbal production was due to articulation difficulties associated with Down syndrome. Unlike children with Williams syndrome who used gestures to access lexical information, children with Down syndrome used gestures to support the expression of

conceptual information (Bello et al., 2004; Caselli et al., 1998; Stefaninis, Caselli, & Volterra, 2007).

Similar to children with Williams syndrome, children with FAS show relative strengths in functional communication, such as naming items or expressing a want or need (Kable & Coles, 2004). Hamilton (1981) conducted a study to investigate the linguistic abilities in children with FAS during social exchanges. The study compared the language performance of children with FAS to children diagnosed with Prader-Willi, a genetic disorder caused by an alteration on chromosome 15. The alteration on chromosome 15 causes mental retardation and physical abnormalities. The FAS group and the Prader-Willi group were compared to a control group of typically developing children. Hamilton's findings showed minimal differences in syntax, single-word identification, and generation of requests and comments among the children in the groups.

Hamilton (1981) suggested that children with FAS produced language more efficiently than the Prader-Willi group yet used simplified language as compared to the control group. Hamilton stated that children with FAS exhibited appropriate turn taking during interpersonal exchanges. But, the children with FAS had difficulties maintaining the stream of conversation and were observed to give verbal responses disconnected from the topic. The author noted that children with FAS appeared to misinterpret the underlying messages of the conversation (Hamilton, 1981). It was not clear if the misinterpretations by the children with FAS were related to difficulties understanding body language, facial expressions, and/or possible deficits in speed of processing the information.

In a case study, Millians, Coles, and Michener (2007) found no difference in the number of gestures used during communication exchanges in a child with FAS, as compared to a child with Attention Deficit Hyperactivity Disorder (ADHD) and a child without a clinical diagnosis. Unlike the child with ADHD and the child without a clinical diagnosis, the child with FAS did not use representative gestures when expressing spatial or nonverbal information (Millians et al., 2007). The findings suggested that there was a difference in the use of representative gestures by the child with FAS. The outcomes from the case study cannot be generalized, but the findings provided a starting point to conduct a systematic study into use of gestures by children with FAS to support thinking and communication.

In summary, gesture use has been investigated in typically developing children and in children with developmental disabilities. The coordinated use of gesture and speech has been shown to support cognitive organization and word retrieval in children with Williams syndrome (Liang et al., 2002; Jarrold et al., 1998). Gestures were found to assist concept formation and expression of thoughts in children with Down syndrome (Bello et al., 2004; Caselli et al., 1998; Stefaninis et al., 2007). However, a general pattern of gesture use by children with developmental disabilities has not been identified.

Given the multiple functions of gestures to facilitate concept formation and communication, this study is to contribute to the understanding of the use of gestures to support learning in a population that has had minimal consideration in the literature (Ryan & Ferguson, 2006). A discussion of the use of gestures by children with and without medical or developmental disabilities is presented in chapter three.

An overview of the study design and procedures are presented in the next section.

1.10 OVERVIEW OF STUDY DESIGN

This exploratory study is to investigate the gesture use by children with FAS while learning the mathematical concept of equivalence. The study implements a microgenetic approach within a quasi-experimental design to examine the gesture use in children with FAS as compared to a control group. This section presents an overview of the study design and procedures. A further discussion of the study design and procedures is presented in chapter four.

1.10.1 Theoretical foundations for the study design

As stated previously, the aims of the study is to examine how children with FAS construct their understanding of the mathematical concept of equivalence through their use of coordinated speech and gestures to demonstrate the changes in thought patterns (Alibali & Goldin-Meadow, 1993; Goldin-Meadow, Kim, & Singer, 1999). Because the changes of children's learning of equivalence are to be examined, a developmental perspective within an empirical study design is selected for this investigation. Developmental research examines changes in behavior of children, adolescents, and adults over a time span (Ho, O'Farrell, Hong, & You, 2006; Karmiloff-

Smith, 1992). There are different types methods used in developmental research to examine change in behaviors over time and include microgenetic studies (Ho et al., 2006; Chinn, 2006).

A microgenetic study, also referred to in the literature as a microdevelopmental study, investigates the changes during the learning process until mastery of the concept or skill is reached (Siegler, 2006). Constant observations are recorded during a defined time period. The information from the observations is analyzed to infer how changes in learning occurred (Siegler, 2006; Granott & Parziale, 2002).

Because gestures are observed to examine how children with FAS construct the understanding of equivalence during a defined time period, a microgenetic approach is considered to be the appropriate method to identify the transitions and changes in learning. The microgenetic approach provides opportunities to investigate the transitions in thought processes while learning a narrowly defined skill (Chinn, 2006).

Previous studies have used a microgenetic framework to investigate children's use of gestures while learning the concept of equivalence. Perry, Breckinridge Church, and Goldin-Meadow (1988) and Alibali and Goldin-Meadow (1993) investigated children's gesture use to formulate concepts and to transition thoughts as they learned how to solve equivalent problems. The studies used gesture observation to determine children's level of understanding during the learning process (Alibali & Goldin-Meadow, 2002). Therefore, this study is based upon the previous research conducted by Perry et al. and Alibli and Goldin-Meadow (1993). These studies applied aspects of a micogenetic approach to investigate children's use of gestures while learning about equivalence and are similar in their objectives and procedures to this study (Perry et al., 1988; Alibali & Goldin-Meadow, 1993).

The following sections discuss the study procedures and statistical methods used for data analysis.

1.10.2 Study procedures

Procedures for this study require each participant 1) to complete an equivalence pretest; 2) to view an instructional video on equivalence; 3) to solve and explain a series of equivalent problems presented in the formats discussed during the video; and 4) to complete a post-test

one week after the pre-test and video. The participants' explanations are video-taped, transcribed, and coded. The gesture and speech coding procedure is based on the methods used in previous studies investigating children's use of gestures while learning equivalence (McNeill, 1992; Alibali & Goldin-Meadow, 1993; Perry et al., 1988).

The speech and gesture units are categorized as either presenting a conceptual understanding of equivalence or presenting an operational interpretation of the equals sign (McNeil & Alibali, 2004; McNeil & Alibali, 2005; Hostetter, Alibali, & Kita, 2007). The gesture units for each category are counted for analysis. The validity and reliability of the pre-test, the post-test, and the gesture coding protocol are discussed in chapters four and five.

1.11 STATISTICAL METHODS

The data is analyzed using inferential statistics. The computer software SPSS version 17 is used to complete the analysis.

1.11.1 Primary study question and hypothesis one

Hypothesis one states that children in the Alcohol Exposed group will have lower scores on the pre-test and the post-test as compared to the children in the Non-exposed group. Independent samples *t* tests are conducted to compare whether there are differences between the pre-test and the post-test scores between the two groups. Additionally, paired samples *t* tests are used to investigate if there were changes between the pre-test and the post-test ($\alpha=.05$) for each group (Gravetter & Wallnau, 2007).

1.11.2 Second study question and hypothesis two

Hypothesis two states that children in the Alcohol Exposed will exhibit a lower number of conceptual gestures as compared to the Non-exposed group. The gesture observations do not fit within a normal distribution therefore the data is analyzed using the non-parametric, chi-square test of independence ($\alpha=.05$) (Gravetter & Wallnau, 2007). The effect size of the difference is calculated using odds ratio.

1.11.3 Third study question and hypothesis three

Hypothesis three states that children who demonstrate few conceptual gestures will score lower on the mathematics post-test. Pearson correlations ($\alpha=.05$) are conducted to investigate whether there are relationships between the use of conceptual gestures and the outcomes on the post-test (Gravetter & Wallnau, 2007).

1.11.4 Exploratory analysis

An exploratory analysis is conducted to investigate whether age and intellectual functioning represented by intellectual quotients (IQ) are associated with gesture use and with the outcomes on the post-test. Pearson correlations ($\alpha=.05$) are conducted to examine if age and/or IQ are related to the scores on the post-test for each group and for the total sample (Gravetter & Wallnau, 2007). Lastly, a multiple regression analysis is conducted to examine if conceptual gestures, age, and/or IQ predict the learning of the mathematical conceptual of equivalence (Gravetter & Wallnau, 2007).

The results from the data analysis are presented in chapter five. Chapter six, the final chapter of the dissertation, discusses the results from the statistical analysis in relation to the current literature on FAS, gestures, and learning.

A summary of chapter one is presented in the next section.

1.12 SUMMARY OF CHAPTER ONE

A synopsis of the relevant points from chapter one is presented below.

- 1) Studies have shown that the prevalence of FAS in the United States and in South Africa is similar to or higher than the prevalence of other developmental disabilities, however, there is a paucity of information regarding specific learning problems and interventions to address the educational needs of children affected by prenatal alcohol exposure (Bertrand et al., 2004; May et al., 2009; Hill et al., 2010; Bertrand, 2009; Kodituwakku & Kodituwakku, 2011).

- 2) Children affected by prenatal alcohol exposure exhibit physical abnormalities and cognitive impairments (Kodituwakku, 2009; Kable & Coles, 2004a). The cognitive impairments associated with the effects from gestational alcohol exposure range from decreased intellectual functioning to deficits in specific cognitive functions. Deficits in cognitive functioning including slow speed of processing, inefficient integration of verbal and visual information, problems manipulating visuo-spatial information, and deficits with processing numerical information are associated with the effects from prenatal alcohol exposure (Kodituwakku, 2009; Jacobson et al., 2011). Additionally, deficits in the areas of working memory and executive functioning are noted in children affected by prenatal alcohol exposure (Burden, Jacobson, & Jacobson, 2005; Kodituwakku, 2009). Deficits in these cognitive processes contribute to secondary learning difficulties, most notably in mathematics, experienced by children with FAS (Howell et al., 2006). A discussion of the abnormalities in the brain structures, the compromises to cognitive functioning, and the deficits in mathematics related to the effects from prenatal alcohol exposure is presented in chapter two.
- 3) Studies have shown that children with and without developmental disabilities use gestures to integrate verbal and visual information, to assist with concept formation, and to their expression of thoughts (Bello et al., 2004; Caselli et al., 1998; Stefaninis et al., 2007). Research investigating gesture use by children with developmental disabilities focused on children with Down syndrome, Williams syndrome, developmental coordination disorders, and speech and language impairments, however, there is minimal research investigating the influence of gestures on the cognitive processes of children affected by prenatal alcohol exposure (Stefaninis et al., 2007; Bello et al., 2004; Caselli et al., 1998; Evans et al., 2001; Millians et al., 2007). According to a review of the literature for this dissertation a common pattern of gesture use by children with developmental disabilities has not been identified (Stefaninis et al., 2007). The use of gestures by children with developmental disorders is discussed in chapter three.
- 4) Children use of gestures while learning the mathematical concept of equivalence to support the integration of information and transitions of previously learned information to form new knowledge (Alibali & Goldin-Meadow, 1993; Perry et al., 1988; Karmiloff-Smith, 1992). Also, studies suggest that children's use of gestures while learning provides a glimpse into their readiness to learn a new concept (Goldin-Meadow, Kim, & Singer,

1999). A discussion of the children's use of gestures while learning mathematics is presented in chapter three.

- 5) As stated in throughout this dissertation, children with FAS exhibit cognitive impairments that cause secondary learning problems (Kable & Coles, 2004a). Though deficits in mathematics are considered to be a core feature of FAS, few studies have examined how children with FAS construct their understanding of mathematics (Jacobson et al., 2011; Kodituwakku, 2009; Kable et al., 2007). The aims of this study are to investigate how children with FAS learn a mathematical concept as facilitated by their use of gestures. First, the study is to extend to the understanding of the mathematical deficits associated with prenatal alcohol exposure by examining how children affected by prenatal alcohol exposure learn the rudimentary mathematical concept of equivalence. Second, the study is to investigate whether children with FAS use gestures to facilitate their understanding of the concept of equivalence. The information gathered from the gesture observation is to contribute to the understanding of the cognitive processes of children affected by prenatal alcohol exposure. Third, the information from the study is to guide the development of effective instructional interventions for children with FAS who often exhibit academic problems in mathematics (Howell et al., 2006).
- 6) The study follows a model of human developmental research that evaluates changes in children, adolescents, and/or adults over a designed time period (Ho et al., 2006). The study implements a microgenetic method that allows researchers to examine subtle transitions in learning until a skill has been mastered through systematic observations (Siegler, 2006). To determine how children with FAS construct their understanding of equivalence, systematic observations of their gesture use occurs. The children's gestures are coded, quantified, and analyzed using inferential statistics. Since this study uses systematic observations over a defined time period to assess changes in learning a specific skill, a microgenetic framework is considered to be the appropriate method to conduct this study (Chinn, 2006; Alibali & Goldin-Meadow, 2002). Chapter four presents a discussion of design methods that are used to conduct this study.
- 7) This empirical study uses a quasi-experimental design that assigns participants to groups according to their diagnosis of FAS, pFAS, or no clinical diagnosis. The participants in each group are matched by age, intellectual functioning, and exposure to similar quality

of education to control for factors that may influence learning. Three study questions, related hypotheses, and an exploratory analysis are investigated in this study. The study design, procedures, and inferential statistic methods used to analyze the data are presented in chapter four. The results from the statistical analysis are presented in chapter five.

- 8) There are limitations to this study that may influence generalization to the larger population. The study is a needs analysis to explore if gestures are a viable method to investigate how children with FAS learn the concept of equivalence therefore the sample size is small and possibly does not reflect the larger population of children affected by prenatal alcohol exposures. Because the study is quasi-experimental, the participants are assigned to groups based upon having a diagnosis of FAS/pFAS or no clinical diagnosis and therefore the findings may reflect group bias. Also, due to the study's investigation of a single mathematical concept, the findings may not be able to be discussed in relation to other mathematical domains. Nevertheless, the study investigates the learning difficulties of a prevalent population in the United States and South Africa that has had minimal consideration in the literature (Bertrand, 2009).

The division of the chapters of the dissertation is presented in the next section.

1.13 CHAPTER DIVISIONS

This dissertation is comprised of six chapters that are described below:

- Chapter One: Overview and Orientation provides a brief summary of the study including a brief discussion of the study's rationale, definition of terms, a brief review of the literature, and an overview of the study design and procedures.
- Chapter Two: Fetal Alcohol Syndrome discusses the diagnostic criteria, the prevalence, and the neurological impairments associated with the effects from prenatal alcohol exposure.

- Chapter Three: Gestures and Learning discusses the relevant studies on gesture use in children with and without developmental disabilities and the importance of gesture use while learning mathematics.
- Chapter Four: Design of the Study discusses the procedures, the procedures used to collect the data and the methods selected for the statistical analysis of the data.
- Chapter Five: Data Analysis and Interpretation presents the results from the statistical analysis and discusses the findings in relation to the study's questions and hypotheses.
- Chapter Six: Conclusions and Recommendations summarize the importance of investigating gesture use of children affected by prenatal alcohol exposure in relation to learning a mathematical concept. Also, the chapter provides information on ways to apply gesture analysis to guide the developmental of educational interventions for children affected by prenatal alcohol exposure.

CHAPTER TWO

FETAL ALCOHOL SYNDROME

2.1 INTRODUCTION

More than thirty years of research has shown that gestational alcohol exposure may cause cognitive impairments and physical alterations to a developing fetus (Jones & Smith, 1973; Bertrand, et al., 2005; Manning & Hoyme, 2007). Despite the evidence of compromises to physical and cognitive development, significant prenatal alcohol exposure continues to be a pervasive cause of birth defects, cognitive impairments, and learning problems (Kodituwakku, 2009; Kable & Coles, 2004a; Jacobson & Jacobson, 2002; Rasmussen & Bisanz, 2009). This chapter presents an overview of the diagnostic criteria for Fetal Alcohol Syndrome (FAS) and the prevalence of children affected by prenatal alcohol exposure in the United States and South Africa. The chapter also discusses the cognitive deficits associated with prenatal alcohol exposure that is considered to impede the learning of mathematics.

2.2 DIAGNOSIS OF FETAL ALCOHOL SYNDROME

In 1973, Kenneth Jones and David Smith indicated a pattern of growth deficiencies, dysmorphia, and alterations to the brain structure associated with significant intrauterine alcohol exposure. The authors based their premise upon information found in the historical record and from the results of their studies of infants born to alcoholic mothers (Abel, 2006). Jones and Smith (1973, p. 999) termed the disorder “Fetal Alcohol Syndrome” and established the groundwork for further investigation into the effects, diagnosis, and treatment of the disorder.

2.2.1 Guidelines for diagnosis of fetal alcohol syndrome

Subsequently, numerous studies have investigated the effects from prenatal alcohol exposure on physical and cognitive development (Abel, 2006). Studies have shown that significant prenatal exposure may cause growth deficiencies and changes to facial features or dysmorphia.

Dysmorphia is defined as abnormalities in the shape or form of human features “caused by genetics or other prenatal influences” (Accardo & Whiteman, 2002, p. 130).

Additionally, significant exposure to alcohol during gestation may compromise the development of the central nervous system. Compromises to the central nervous system may be exhibited by microcephaly, an abnormally small head circumference that suggests reduced brain volume, damage to specific structures of the brain, and/or deficits in cognitive functioning (Accardo & Whiteman, 2002; Bertrand et al., 2004; Kable & Coles, 2004a; Koditiwakku, 2009).

The cognitive impairments associated with the effects from prenatal alcohol exposure range from global intellectual impairments to specific processing deficits such as decreased processing speed, problems with encoding, and/or inefficient integration of verbal and visual information (Kable & Coles, 2004a; Chasnoff, Wells, Telford, Schmidt, & Messer, 2010; Burden et al., 2009; Koditiwakku, 2009).

Though numerous studies have shown that significant prenatal alcohol exposure may cause a spectrum of physical and neurodevelopmental deficits, researchers continue to debate the threshold of prenatal alcohol exposure that causes physical abnormalities and brain damage as well as the criteria for an FAS diagnosis (Abel, 2006; Bertrand et al., 2005). This resulted in a lack of uniformity in diagnostic procedures that confound the findings from studies investigating prevalence rates and outcomes from treatment studies (Urban et al., 2008). Attempts have been made to develop consistency in the diagnostic procedures when evaluating for FAS.

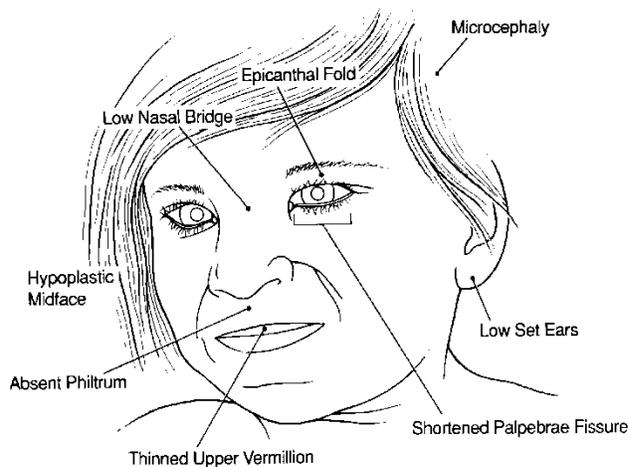
In 1996, the Institute of Medicine (IOM) developed guidelines in an attempt to establish consistency in diagnosing FAS (Stratton et al., 1996). The IOM identified four criteria to consider when evaluating for FAS: 1) dysmorphia, 2) growth retardation, 3) central nervous system damage, and 4) documented history of maternal alcohol consumption during pregnancy (Bertrand et al., 2004; Stratton et al., 1996). Researchers determined that the IOM guidelines lacked specificity regarding the dysmorphic features, the growth delays, and the cognitive impairments associated with the effects from prenatal alcohol exposure (Bertrand et al., 2004; Bertrand et al., 2005; Stratton et al., 1996). Yet, the IOM guidelines provided a starting point for clinicians and researchers to refine the diagnostic criteria.

In 2002, the United States Congress mandated the Centers for Disease Control and Prevention (CDC) to develop explicit diagnostic criteria to assess disorders related to prenatal alcohol exposure, to disseminate the information to medical practitioners, and to incorporate the information into the curriculum for medical students (Bertrand et al., 2005). The CDC formed a Scientific Working Group comprised of clinicians and researchers knowledgeable in the effects from prenatal alcohol exposure from federal agencies, research institutions, and non-governmental organizations. The Scientific Working Group and the National Task Force on Fetal Alcohol Syndrome and Fetal Alcohol Effects updated the IOM guidelines by specifying the physical and cognitive features needed to a diagnosis of FAS or pFAS (Bertrand et al., 2005). The CDC published the updated guidelines in 2004.

2.2.2 Criteria for diagnosing fetal alcohol syndrome

According to the 2004 guidelines, three facial abnormalities or dysmorphic features need to be present: 1) a smooth philtrum, 2) a thin vermilion border of upper lip, and 3) shortened palpebral fissures (Astley, 2004; Manning & Hoyme, 2007). In addition to changes to the philtrum and the vermilion border, evidence of shortened palpebral fissures or eye openings, measured below the 10th percentile as compared to the national average, need to be present (Bertrand et al., 2004). The presence of dysmorphic features is determined according to racial norms (Bertrand, et al., 2005). Figure 1 provides an example of the common dysmorphic facial features found in children with FAS.

Figure 1: Example of Facial Dysmorphia Associated with FAS. Reprinted by permission of the Maternal Substance Abuse and Child Development Program, Emory University, School of Medicine, Atlanta, Georgia.



The 2004 diagnostic guidelines suggested that evidence of prenatal and/or postnatal growth delays need to be confirmed. Delays in growth are shown by height, weight or both measured at or below the national 10th percentile and adjusted for gestational age, current age, gender, as well as for race and ethnicity (Bertrand et al., 2004, p. vii; Bertrand et al., 2005).

In addition to dysmorphia and growth deficiencies, evidence of central nervous system abnormalities need to be present. Anomalies in the central nervous system may be exhibited by changes in the brain structure, neurological problems, and/or functional deficits (Bertrand et al., 2004; Bertrand et al., 2005). Structural abnormalities may be exhibited by a small head circumference or microcephaly measured below the 10th percentile when adjusted for age and gender. Compromises to the central nervous system may be detected through the use of imaging techniques. Studies using imaging techniques have found a reduction in brain volume, alterations to the size and shape of the corpus callosum, cerebellum, and/or basal ganglia, as well as inconsistencies in white matter integrity associated with the effects from prenatal alcohol exposure (Bertrand et al., 2004; Fryer et al., 2009; Li, Coles, Lynch, & Hu, 2009; Lebel et al., 2008).

Not all children with FAS exhibit a small head circumference or abnormalities in brain structure viewed through imaging, but may display neurological problems or functional deficits. Neurological problems, such seizures or motor difficulties may be attributed to prenatal alcohol exposure if they cannot be explained by other medical causes or postnatal injuries (Bertrand et al., 2004)

According to the 2004 guidelines, overall cognitive impairments or functional deficits in at least three domains need to be present to receive a diagnosis of FAS (Bertrand et al., 2004). Global intellectual deficits are determined by scores that fall at or below the 3rd percentile or two more standard deviations below the mean on standardized tests that assess cognitive ability and adaptive functioning (Bertrand et al., 2004; Bertrand et al., 2005). Functional or processing deficits are identified by cognitive discrepancies among verbal, spatial, and nonverbal reasoning, or developmental delays, deficits in executive functioning, attention, motor skills, social skills, and/or in language pragmatics. Scores on standardized tests that assess the functional domains need to fall at or below the 16th percentile or at least one standard deviation below the mean (Bertrand et al., 2004).

The 2004 guidelines suggested that documented evidence of maternal alcohol consumption during pregnancy is preferred, however, children who exhibit alcohol-related dysmorphia, microcephaly, growth deficiencies, and cognitive deficits not accounted for by other genetic, developmental, or medical factors, may receive a diagnosis of FAS without documentation of maternal alcohol use during pregnancy (Kable & Coles, 2004a; Bertrand et al., 2005). Children who have alcohol related dysmorphia, exhibit one of the two core features associated with intrauterine alcohol exposure, and have documented evidence of prenatal alcohol exposure may receive a clinical diagnosis of pFAS (Kable & Coles, 2004a; Bertrand et al., 2004).

Multiple terms are used to describe the effects from prenatal alcohol exposure. Fetal Alcohol Spectrum Disorders (FASD) is used to describe the range of effects associated with prenatal alcohol exposure and include the medical diagnoses of FAS and pFAS as well as the terms of Alcohol Related Birth Defects (ARBD) and Alcohol Related Neurodevelopmental Disorder (ARND). ARBD and ARND are used to describe the physical alterations and/or the cognitive impairments associated with prenatal alcohol exposure in individuals who do not meet the criteria to receive a diagnosis of FAS or pFAS (Kable & Coles, 2004a; Bertrand et al., 2004).

2.2.3 Evaluating for fetal alcohol syndrome

A multitude of factors are needed to be considered when determining whether children prenatally exposed to alcohol meet the criteria to receive the diagnosis of FAS or pFAS. The evaluation would need to be conducted by an interdisciplinary team professionals trained to discern the characteristics of FAS from other developmental disabilities (Bertrand et al., 2004; Kable & Coles, 2004a). The interdisciplinary team would need to include professionals from the fields of medicine, psychology, social work, education, rehabilitation/habilitation services, and family advocacy.

Fetal Alcohol Syndrome is a medical diagnosis. Children affected by prenatal alcohol exposure present physical and cognitive traits found in other medical and developmental disorders. For example, children with Williams syndrome, a genetic disorder caused by a microdeletion on chromosome 7q11.23, exhibit similar dysmorphic features and cognitive impairments (Nakamura et al., 2001; Bertrand et al., 2004; Manning & Hoyme, 2007). Therefore, the interdisciplinary team needs to include a geneticist or a developmental pediatrician trained to distinguish the

dysmorphic features and growth deficiencies associated with FAS that overlap with traits from other genetic disorders or medical conditions.

The team needs to consist of clinical psychologists trained to evaluate and discern the variability in cognitive functioning and development in children. Social workers are needed to gather comprehensive family histories regarding prenatal care, exposures to toxins, as well as to provide supportive services. Special educators are needed to evaluate learning needs and contribute to treatment planning. Additionally, specialists such as speech and language pathologists and occupational therapists are needed to provide evaluations and therapeutic services when warranted (Kable & Coles, 2004a; Bertrand et al., 2004).

A comprehensive evaluation conducted by an interdisciplinary team of professionals is preferred to ensure the accuracy of the diagnosis and to develop effective treatment plans in order to prevent secondary disabilities such as depression or learning disorders (Lynch, Coles, Corley, & Falek, 2003; Kable & Coles, 2004a; May et al., 2000; Ryan & Ferguson, 2006).

Children affected by prenatal alcohol exposure are found across geographical regions, cultures, and socio-economic groups. As stated in chapter one, studies have indicated that the prevalence of FASD may be as high or higher than other developmental disabilities, including Spina Bifida and Fragile X, and may affect as much as 2 to 7 percent of school age children in the United States and in other countries (May et al., 2009; Hoyme, 2009, p.176; Cordeiro, Ballinger, Hagerman, & Hessler, 2011; Shin et al., 2010).

The following section will discuss the prevalence of FAS in the United States of America and South Africa.

2.3 PREVALENCE OF FETAL ALCOHOL SYNDROME

The estimated prevalence of FAS varies according to study design, the population studied, and geographical regions. In 2001, May and Gossage reviewed prevalence studies conducted in the United States and in other regions to summarize the occurrence of FAS. May and Gossage (2001) defined prevalence “as the frequency of occurrence of FAS, alcohol related birth defects, alcohol-related neurodevelopmental disorders among the study population and any subgroups

within the population at all time periods during the life span” (p.60). Their definition of prevalence is used to indicate the estimated occurrence of FAS in this chapter.

2.3.1 Methodology for studying prevalence

May and Gossage (2001) analyzed studies that utilized three different methodologies to determine the prevalence of FAS. The three methodologies reviewed were 1) passive system studies, 2) clinic-based studies, and 3) active case ascertainment methods. Passive system and clinic-based studies are considered to be the two most common methods to study prevalence in the United States and in Europe (Viljoen et al., 2005, p. 593). The passive system, clinic-based, and active case ascertainment methodologies are discussed in the next sections.

2.3.1.1 *Passive system*

Researchers conduct passive system studies by reviewing the available birth and health records for a population or a location to gather information about the prevalence of the effects from prenatal alcohol exposure. Researchers have suggested that the findings from passive system studies possibly underestimate the occurrence of FAS due to the variation in the quality and the accuracy of the information (May and Gossage, 2001; Viljoen et al., 2005). Passive system studies are conducted because they are cost efficient. The use of available records allows investigators to examine patterns of prenatal alcohol exposure without the cost of conducting large scale studies to collect raw data directly from a designated region or population.

2.3.1.2 *Clinic-based studies*

Investigators conduct clinic-based studies by gathering data from patients receiving care at a clinic or at a hospital. Study participants are recruited from clinics that provide health services in a targeted region or location. (May & Gosage, 2001). Researchers have cautioned that clinic-based studies may over or under represent the number of children prenatally exposed to alcohol and/or reflect demographics the clinic where the study was conducted. Therefore, the findings may not be generalized across geographical locations.

2.3.1.3 Active case ascertainment

Active case ascertainment is used to study the prevalence of FAS within a particular population, geographical region, or location. Researchers recruit children suspected of having FAS within the designated area or population (May & Gossage, 2001). Investigators request participants to complete an evaluation to confirm a diagnosis of FAS. The information gathered from the evaluation regarding the diagnosis of FAS is incorporated into the data.

Researchers have found that active case ascertainment studies often reveal high rates of FAS within a particular area or population. Frequently, active case ascertainment studies are used to study the prevalence of FAS in high risk areas and may over-represent the number of cases within that population or location (May & Gossage, 2001; Viljoen et al., 2005). Similar to the previous methodologies discussed, the results from active case ascertainment studies may not be generalized to the larger population or across geographical regions.

A discussion of the prevalence of FAS in the United States and in South Africa occurs in the next sections.

2.3.2 Passive system studies and prevalence in the United States

Comparison of findings from passive systems showed variations in the number of cases of FAS across demographics (May & Gossage, 2001) Using a passive system that reviewed birth records, researchers from the CDC Birth Defects Monitoring Program, a national program that monitors congenital malformations among infants, approximated that the rate of children with FAS was 2.0 per 10,000 births between 1979 and 1992 (Centers for Disease Control, May 7, 1993, p.339). Subsequently, May and Gossage (2001) reported the approximated prevalence of FAS in the United States to be between 0.5 and 2.0 cases per 1,000 births (p.166). It is suggested that the variations in the reported rate of FAS in the United States and in other countries are related to the socio-economic status of the population, the cultural acceptance of drinking patterns in the area, the number of high risk communities, such as in the Native American populations (Viljoen et al., 2005; May & Gossage, 2001; Centers for Disease Control, July 18, 2003).

In the United States, Native American populations, specifically populations living on reservations in the western United States, are considered to be high risk populations (May & Gossage, 2001; Ryan & Ferguson, 2006). The CDC reported that, “the rate of FAS for American Indians is higher than other racial/ethnic groups in the United States” (Centers for Disease Control, April 7, 1995, p. 255). The estimated number of children with FAS between the years of 1980 to 1982 in the Native American population ranged from 1.4 per 1000 births among the Navajo population to 9.8 per 1000 live births among the American Indians of the Southwestern Plains (Centers for Disease Control, April 7, 1995, p. 255). In contrast, the number of cases reported by the CDC between 1989 and 1992 estimated the overall rate of FAS in the state of Georgia in the United States to be 2.3 per 10,000 live births (Centers for Disease Control, April 7, 1995, p.252). The prevalence of FAS in Caucasians in the United States around the same time was estimated to be 0.09 per 1,000 births (May & Gossage, 2001, p.163).

Because these studies utilized passive system methodology, the accuracy of the diagnosis and the reporting from healthcare providers could not be controlled. As stated previously, this method is considered to yield lower prevalence rates. Regardless, the findings illustrated the variance of reported occurrence of FAS across regions and ethnic groups. This provides information of targeted areas or populations that would benefit from an increase in interventions to prevent prenatal alcohol exposure and access to supportive services for those with the diagnosis.

2.3.3 Passive system and case ascertainment prevalence studies in South Africa

In 2001, investigators from the National Institutes of Alcoholism and Alcohol Abuse reported that in one wine growing region of the Western Cape Province of South Africa, prevalence of FAS was between 40.5 and 46.6 per 1,000 children between the ages of 5 and 9 years old (Centers for Disease Control, July 18, 2003, p. 660). Prevalence was higher in the Western Cape Province as compared to most areas in the United States.

Viljoen, Gossage, Brooke, Adnams, Snell, Khade, Koditwakku, Asante, Findlay, Quinton, Morais, Kalberg, and May (2005) conducted a prevalence study in the Western Cape Province of South Africa using the active case ascertainment method. The researchers evaluated children in the first grade of elementary school in the region. The results indicated that the prevalence rate in

the Western Cape Province was approximated to be 65.2-74.2 per 1,000 children in the first grade (Viljoen et al., 2005, p. 594). The authors suggested that the increase in the number of children diagnosed with FAS was related to the refined study methods, social changes, and to an increase in the availability of commercially produced alcoholic beverages (Viljoen et al., 2005). The studies suggested that the prevalence rates of FAS in the Western Cape Province of South Africa to be one of the highest among nations that report FAS (Viljoen et al, 2005).

Further studies were conducted to explore whether the high rate of children with FAS was a particular characteristic of the wine growing region of the Western Cape Province. Investigators from the CDC, the University of Witwatersrand, and the Foundation for Alcohol Related Research in Johannesburg, South Africa conducted a prevalence study in the Gauteng Province, a non-wine growing region of South Africa (Centers for Disease Control, July 18, 2003). The median prevalence of FAS in the Gauteng Province of South Africa was approximated to be 26.5 cases per 1,000 children (Centers for Disease Control, July 18, 2003, p. 61). The findings suggested that a high number of children with FAS also were found in areas outside of the Western Cape Province. Additionally, the investigators surmised that the number of children affected by prenatal alcohol exposure may be underestimated due to the lack of adequate prenatal and postnatal healthcare, surveillance, and monitoring by intervention programs (Centers for Disease Control, July 18, 2003).

2.3.4 Active case ascertainment in-school prevalence studies in the United States and South Africa

More recently, May, Gossage, Kalberg, Robinson, Buckley, Manning, and Hoyme (2009), investigated the prevalence of FASD utilizing a specific type of an active case ascertainment study that screened children for FASD at school. In-school studies are considered to be an efficient method to approximate prevalence in a given population (May et al, 2009). According to May et al., in-school studies provide researchers access to a stable, representative sample of a targeted population. The authors indicated that collaboration with the local schools lends credibility to the studies and reassures reluctant parents thus lessening the number of participant drop-outs or noncompliance to the protocols. Also, collaboration with local schools provides researchers access to reliable information about children's health, development, and cognitive function (May et al., 2009). In-school studies have been used to estimate prevalence of FASD in South Africa, Italy, and the United States.

Urban, Chersich, Fourie, Chetty, Olivier, and Viljoen (2008) conducted in-school screening studies to estimate the prevalence of FAS and pFAS among first graders in the towns of De Aar and Upington in the Northern Cape Province of South Africa. The prevalence rate of De Aar was approximated to be 119.4 cases out of 1,000 children (Urban et al., 2008, p.879). The estimated prevalence rate for Upington was 74.7 cases out of 1,000 children (Urban et al., 2008, p.879). The overall estimated prevalence was 62.2 cases out of 1,000 children in the Northern Cape Province (Urban et al., 2008, p.879). The prevalence rate in the Northern Cape Province was higher than earlier prevalence studies conducted in the Western Cape Province, a region noted to have the highest prevalence rate of children with FAS (Urban et al., 2008, Viljoen et al., 2005). It was not clear as to whether the high prevalence of FAS in the Northern Cape Province as compared to the prevalence rates in the Western Cape Province would be skewed given the differences in the type of study methods used.

The results from the in-school screening studies showed an increase in the prevalence of FASD as compared to previous studies using passive or clinic-based methodology (May et al., 2009). The overall average prevalence rate of FASD in South Africa was estimated to be 72.3 cases out of 1,000 children (May et al., 2009, p.188). The mean prevalence rate of FASD in Italy was approximated to be 35.7 cases out of 1,000 children, and the prevalence rate was estimated to be 16.5 cases out of 1,000 children in the United States (May et al., 2009, p. 189). It is possible that the increase in the estimated prevalence is attributed to the inclusion of children with FASD in the populations studied. Nevertheless, the studies indicated that FASD is a pervasive problem throughout regions of South Africa, Italy, and the United States.

2.3.5 Challenges to studying prevalence of fetal alcohol syndrome

Determining the prevalence rate of FAS is confounded by various factors. The selection of methodologies used to study prevalence, the differences of accepted alcohol use among groups, and the higher reported rates of FAS among disadvantaged and lower socio-economic groups, as well as inconsistencies in diagnosing would limit the scope of the data used to determine the occurrences of FAS (Urban et al., 2008). These factors possibly would contribute to the misrepresentation of the number of children considered to be at risk for FAS in South Africa, the United States, and in other countries (Urban et al., 2008).

Regardless of the study method, the estimated prevalence rate of FAS is comparable to other developmental disabilities such as Down syndrome or Spina Bifida (Bertrand et al., 2004; Shin et al., 2010). Often genetic and development disorders with similar prevalence rates as FAS have had extensive research into effective interventions to support the child as they mature (Ryan & Ferguson, 2006). Yet many children who are affected by prenatal alcohol exposure do not receive the appropriate diagnosis or have access to the interventions and educational supports they need because of cultural and economic factors that influence society's awareness and perspective of the disorder (Centers for Disease Control, April 7, 1995; Centers for Disease Control, July 18, 2003; Stade, Stevens, Ungar, Beyene, & Koren, 2006; McKinstry, 2005).

The next section will provide an overview of the effects associated with prenatal alcohol exposure that interfere with learning and mathematics.

2.4 NEUROLOGICAL IMPAIRMENTS ASSOCIATED WITH FETAL ALCOHOL SYNDROME

The effects from prenatal alcohol exposure vary among individuals. The amount, the duration, and the timing of maternal alcohol consumption during pregnancy influence the severity of the effects on the developing fetus (Able, 2006; Kable & Coles, 2004a; Bertrand et al., 2005). Other factors that may contribute to alcohol's effects on a developing fetus include the biological mother's age, health, metabolic system, and access to prenatal care and services due to socio-economic status (Kable & Coles, 2004a; Floyd, O'Connor, Sokol, Bertrand, & Codero, 2005). Not all children exposed to heavy maternal alcohol use during pregnancy are affected. Abel (1995; 2006) reported that approximately 40.5 percent of children born to alcoholic mothers met the criteria to receive a diagnosis of FAS or pFAS.

As noted in the earlier sections, cognitive impairments varying from low intellectual functioning to specific learning disabilities are associated with FAS (Kable & Coles, 2004a). Deficits in encoding, weaknesses with processing visual-spatial information, and decreased processing speed are associated to the effects from prenatal alcohol exposure (Dodge et al., 2009; Coles, Lynch, Kable, Johnson, & Goldstein, 2010; Kodituwakku, 2009; Mattson & Roebuck, 2002; Uecker & Nadel, 1996; Kaemingk & Halverson, 2000). Also, problems with attention, working

memory, cognitive flexibility, and other aspects of executive functioning have been attributed to the effects from gestational alcohol exposure (Aragon et al., 2008; Vaurio, Riley, & Mattson, 2008; Mattson et al., 2006; Coles, 2001; Coles, Platzman, Lynch & Freides, 2002). Studies continue to explore whether the reported deficits in attention are a result of the brain damage caused by maternal use of alcohol during pregnancy or the result of some other confounding variable (Kooistra, Crawford, Gibbard, Ramage, & Kaplan, 2009; Vaurio et al., 2008).

The following sections discuss the specific impairments associated with the effects from prenatal alcohol exposure that hinder learning.

2.4.1 Integration of information and processing speed

Research has indicated that prenatal alcohol exposure causes damage to the corpus callosum, a structure of the brain that contains white matter tracks and connects the left and right hemispheres. White matter consists of myelinated nerve axons that transfer signals from one brain area to another to (Accardo & Whitman, 2002; Ma et al., 2005). Damage to the corpus callosum and to the white matter has been found to impair integration of verbal and visual stimuli and speed of processing (Ma et al., 2005; Roebuck-Spencer, Mattson, Marion, Brown, & Riley, 2004).

Roebuck-Spencer, Mattson, Marion, Brown, and Riley (2004) conducted a study to investigate damage in the corpus callosum in children affected by prenatal alcohol exposure and the influence on the integration of information. The children in the study were administered the Bimanual Coordination Test to measure the contribution of the corpus callosum in the integration of premotor and sensorimotor information.

The test was administered to thirty-seven children with FASD between the ages of 10.0 to 19.8 years and to a control group of children between the ages of 10.4 to 19.9 years. The results indicated that the FASD group was able to complete that visual motor task as accurately as the Control group. However children in the FASD group took a longer amount of time to navigate spatial layout of the test as compared to the Control group (Roebuck-Spencer et al., 2004).

The authors concluded that the effects from prenatal alcohol exposure damaged the corpus callosum and impeded the efficiency of the integration of stimuli to complete the bimanual

coordination task. These findings were commensurate with other studies that indicated children with FAS have difficulties integrating information to complete visual motor and visual-spatial tasks (Adnams et al., 2001; Uecker & Nadel, 1996).

Diffusion Tensor Imaging (DTI), an imaging method that “measures the diffusion of water in brain tissue across different noncolinear directions, or anisotropy, to aid in visualization of the tissue organization in the brain” has been used to investigate the integrity of the white matter in the corpus callosum in children, adolescents, and young adults prenatally exposed to alcohol (Ma, Coles et al., 2005, p.1251). Results from studies using DTI have found inconsistencies in the white matter of the brain and changes to the structure of the corpus callosum that possibly hinder the integration of information and efficient processing (Ma et al, 2005; Lebel et al., 2008).

Lebel, Rasmussen, Wyper, Walker, Andrew, Yager, and Beaulieu (2008) conducted a study to measure the white matter integrity in twenty-four children diagnosed with FASD as compared to a control group of ninety-five children between 5 and 13 years using DTI. The results from the study concurred with studies indicating abnormalities in the corpus callosum (Ma et al, 2005). Additionally, the findings indicated that compromised white matter extended beyond the corpus callosum. The authors suggested that DTI may be used to identify “key structural brain abnormalities that presumably underlie cognitive motor, behavioral, and emotional difficulties associated with FASD” (Lebel et al., 2008, p.1739).

Other studies using DTI have found compromises to the corpus callosum in children and young adults affected by prenatal alcohol exposure. Wozinak, Myetzel, Bryon, Mueller, McGee, Freerks, Ward, Nelson, Change, and Lim (2009) investigated the microstructure of corpus callosum. Their results showed abnormalities in the posterior of the corpus callosum associated with the effects from prenatal alcohol exposure. The authors surmised that changes to the posterior region of the corpus callosum might interfere with processing information and regulating behavior.

Li, Coles, Lynch, and Hu (2009) conducted a study using DTI and found degraded white matter integrity in the isthmus of the corpus callosum in young adults with significant alcohol related dysmorphia as compared to a control group of young adults exposed to alcohol but who did not exhibit dysmorphia. Li et al. concluded that prenatal alcohol exposure compromises integrity of white matter in the corpus callosum and in surrounding structures. The authors suggested that

the white matter damage in this region may contribute to the functional and behavioral deficits associated with FAS.

Freyer, Schweinsburg, Bjorkquist, Frank, Mattson, Spadoni, and Riley (2009) investigated white matter microstructure in youth ages eight through eighteen with FASD and without a history of significant alcohol exposure using DTI. Again, the results were commensurate with other studies suggesting compromised white matter integrity in youth with FASD. The authors proposed that the reduction of white matter in the frontal and occipital regions may be associated with inefficient processing and attention (Freyer et al., 2009).

Processing refers to the speed and efficiency to attend, encode, manipulate, as well as to respond to stimuli (Burden, Jacobson & Jacobson, 2005). Burden, Jacobson, and Jacobson conducted a study to investigate the processing speed and efficiency in children aged 7.5 years affected by prenatal alcohol exposure. Using the Sternberg Memory Scanning Test, a mental rotation task, a number comparison task, an arrow discrimination task, and the Stroop Color Naming Test, the investigators measured the participants' automatic and complex processing abilities and speed. Processing speed in the alcohol-affected group was not suppressed on tasks that required automatic processing and recall. However, children affected by prenatal alcohol exposure exhibited slower processing speed on tasks that required mental manipulation of information, especially visual-spatial information.

The authors suggested that the reduction in processing speed on tasks that taxed cognitive demands impact the efficiency of the working memory system (Burden, Jacobson, & Jacobson, 2005; Kopera-Frye et al., 1996). Difficulties in these areas interfere with academic functioning especially in mathematics.

Deficits in attention have been noted in children affected by prenatal alcohol exposure. However, studies have been inconclusive as to whether prenatal alcohol exposure directly relates to the described attention deficits or is better explained by the evidence of white matter damage that would hinder efficient processing speed and encoding.

A discussion of the construct of attention in relation to the effects from prenatal alcohol exposure occurs in the next section.

2.4.2 Attention and working memory

Attention refers to the “functional relationships between certain qualities of environmental events (objects, actions, and their properties) and the general forms of responses to them (initiation, sustainment, inhibition, and shift)” and involves the use of multiple cognitive and physiological processes (Barkley, 1996, p. 308).

Children affected from prenatal alcohol exposure frequently are misdiagnosed as having Attention Deficit Hyperactivity Disorder (ADHD) due to the similarities of the observed characteristics in the disorders. Studies examining the characteristics of attention in school aged children affected by prenatal alcohol exposure as compared to children diagnosed with ADHD have found differences in their abilities to initiate, maintain, and shift attention as well as in their processing patterns (Coles, 2001; Coles, Platzman, Lynch & Freides, 2002).

Coles (2001) conducted a study comparing children with FAS and fetal alcohol effects (FAE) to children diagnosed with ADHD. The mean age of the children who participated in the study was 7.63 years. Coles (2001) examined aspects attention based upon the four factor model devised by Mirsky (1996). Subsequently Mirsky has extended the model to incorporate five factors of attention (see Mirsky, Pascualvaca, Duncan, & French, 1999). Mirsky's early model divided the construct of attention into four functions that could be assessed. The four-factors were “1) focus/execute, 2) shift, 3) sustain, and 4) encode” (Mirsky, 1996, p. 76).

Based upon Mirsky's four factor model, Coles (2001) examined the following four factors of attention: 1) focus, 2) encode, 3) shift, and 4) sustain. These factors were investigated using standardized assessments as well as computerized tests to measure vigilance and sustained attention (Coles, 2001). The study found differences in attention and in impulsivity between the FAS-FAE group and the ADHD group. The findings indicated that children in the FAS-FAE group performed poorly on encoding information to support new learning and flexibly applying problem solving strategies to complete tasks. Also, the results suggested that the children in FAS-FAE group exhibited difficulties completing tasks that required visual-spatial processing. The children in the ADHD group displayed difficulties with focusing, sustaining attention, and showed an increased pattern of impulsive behaviors as compared to the children in the FAS-FAE group. Coles (2001) proposed that the children with ADHD demonstrated global attention problems that impacted their behavior across settings. The global problems in attention and patterns of

impulsivity were not found in children in the FAS-FAE group. Coles (2001) concluded that the dissimilarities in the profiles between children with FAS-FAE and ADHD could imply differences in the neurocognitive deficits associated with the disorders.

In a later study, Coles, Platzman, Lynch, and Freides (2002) explored sustained auditory and visual attention in adolescents with affected by gestational alcohol exposure. The results from this study suggested that the adolescents, prenatally exposed to alcohol, exhibited impairments in their ability to sustain visual attention. The authors proposed that the weaknesses in visual attention could be related to the deficits in visual processing. General deficits in attention were not found in the adolescents with FAS (Coles et al., 2002).

More recently, Mattson, Calarco, and Lang (2006) investigated the characteristics of attention in children affected by prenatal alcohol exposure between 9 and 14 years old compared to a control group of children within the same age range not exposed to alcohol during gestation. A computerized test of attention that measured visual focus, auditory focus, and auditory–visual shift was administered to assess attention in the participants, reaction time, and impulsivity.

The children in the FASD group displayed deficits in focused visual attention and a slower response time compared to the Control group. Also, the children in the FASD group exhibited a longer response time to switch between verbal and visual stimuli. Global deficits in attention were not found in the FASD group (Mattson et al., 2006). Mattson, Calarco, and Lang suggested that difficulties sustaining attention as the intervals between the presentations of stimuli increased could reflect weaknesses maintaining information in the working memory system.

Working memory is a multiple component system that transforms, integrates, and maintains information for additional processing and use (Gathercole, Pickering, Ambridge, Wearing, 2004). Logie and Della Salla (2005) described working memory as a “system for representing interpreted objects and scenes, allowing us to interact with and mentally manipulate those objects” (p.95). Deficits in working memory are associated with the effects from prenatal alcohol exposure (Burden, Jacobson, Sokolo, & Jacobson, 2005).

Burden, Jacobson, Sokolo, and Jacobson (2005) investigated working memory in children with FASD. The authors surmised that a slow response or recognition of visual and/or orally presented stimuli would impact the ability to gather and process information in working memory

in the FASD group. Burden et al. proposed that it would require greater cognitive effort to respond succinctly when alternating between verbal and visual modalities (Mattson et al., 2006). This would influence attention and processing information efficiently.

The findings from the Mattson, Calarco, and Lang (2006) study drew similar conclusions regarding attention in children affected by prenatal alcohol exposure to the findings from the Coles (2001) and Coles et al. (2002) studies. Research has suggested that weaknesses in visual attention may be associated with the effects from prenatal alcohol exposure. More notably, children with FAS displayed deficits in encoding, processing speed, and integrating verbal and visual stimuli that are a result of brain damage and not linked to global deficits in attention (Ma et al., 2005; Coles, 2001; Roebuck-Spencer et al., 2004; Mattson et al., 2006; Burden et al., 2005).

The findings regarding the impact of prenatal alcohol exposure on attention have been inconclusive. Coles (2001) and others have suggested that additional studies are needed in order to discern the attention patterns from other cognitive impairments in children with FAS.

There is a close relationship among attention, arousal regulation, encoding, and efficient processing of information. Inefficient encoding has been noted in children prenatally exposed to alcohol (Mattson & Roebuck, 2002; Roebuck & Matteson, 2004; Willford et al., 2004). Children affected by prenatal alcohol exposure often exhibit deficits with encoding information. In a classroom setting, it can be difficult to discern the differences between weaknesses in attention and inefficient encoding information.

The next section discusses the deficits with encoding information associated with the effects from prenatal alcohol exposure.

2.4.3 Encoding

Encoding refers to the ability to create mental representations for further processing and/or storage in memory (Willford et al., 2004; Sergeant, 1996). More complex forms of encoding entail retention, processing load, and the time it takes to make a decision (Sergeant, 1996).

Inefficient processing and encoding of environmental stimuli have been found in infants as young as six months of age categorized as high risk due to reported maternal alcohol consumption during pregnancy (Kable & Coles, 2004b). Kable and Coles (2004b) evaluated information processing in infants by measuring their cardiac responses to auditory and visual stimuli. Their findings indicated that infants at high risk took longer to respond to visual and auditory stimuli as indexed by their first point of decelerative heart rate response. The slower response time would be indicative of difficulties to initiate attention to stimuli and interfere with ability to glean information from their surroundings.

Slower response times have been noted in school-aged children affected by prenatal alcohol exposure and may hinder their ability to attend, process, and encode information in order to learn (Kable & Coles, 2004b; Burden et al., 2009; Mattson et al., 2006; Roebuck-Spencer et al., 2004; Coles, 2001). Studies investigating school-aged children affected by prenatal alcohol exposure have noted weaknesses in encoding visual stimuli (Uecker & Nadel, 1996; Matteson & Roebuck, 2002; Kaemingk & Halverson, 2000). However, studies have been inconsistent with identifying a specific weaknesses with encoding verbal information in children with FAS (Mattson & Roebuck, 2002; Roebuck-Spencer & Mattson, 2004; Kemingk, Mulvaney, & Halverson, 2003; Williford et al., 2004).

Roebuck-Spencer and Mattson (2004) reviewed the performance of children prenatally exposed to alcohol to a control group of age-matched peers who exhibited a typical developmental profile on the California Verbal Learning Test-Children's version (CVLT-C) and on the Verbal Learning subtest from the Wide Range Assessment of Memory and Learning (WRMAL). The purpose of the review was to explore patterns of retention of verbal information in children affected by prenatal alcohol exposure.

The analysis showed that the FASD group showed similar retention of verbal information as compared to the control group on the CVLT-C. Roebuck-Spencer and Mattson conducted an error analysis of the response patterns from the CVLT-C. Their findings suggested that the FASD group utilized semantic clustering strategies to assist in their recall of the presented word lists. The authors proposed that the format of the CVLT-C provided opportunities for the FASD group to receive additional exposure to the stimuli and supported their performance on this measure. The FASD group did not exhibit a similar performance pattern compared to the control group on the Verbal Learning subtest from the WRMAL (Roebuck-Spencer & Mattson, 2004).

Roebuck and Mattson proposed that the format of the Verbal Learning subtest from the WRMAL neither provided repeated exposure to the stimuli nor provided a layout that enabled the children in the FASD group to devise strategies to support retention.

Roebuck-Spencer and Matteson (2004) indicated the comparable performance between the two groups on the CVLT-C did not show a relative strength in verbal abilities in the FASD group. Their findings presented conflicting information regarding the assumed intact verbal processes in children with FASD (Mattson & Roebuck, 2002; Williford et al., 2004; Kaemingk et al., 2003). Roebuck-Spencer and Mattson showed the need for children with FASD to receive repetition and additional exposure to stimuli to support learning.

In addition to weaknesses with integration of information, processing speed, and working memory, many children with FAS exhibit deficits processing visual-spatial information. This is discussed in the next section.

2.4.4 Visual-spatial skills

Deficits processing visual-spatial information have been associated with the effects from prenatal alcohol exposure (Kable & Coles, 2004a; Uecker & Nadel, 1996; Sampson et al., 1997).

Visual-spatial processing refers to the ability to perceive visual stimuli, mentally represent the information, and manipulate the information for further use. Specifically, visual refers to the ability to perceive “the color, shape, contrast, size, visual texture, and location of an object or scene relative to one another with respect to a particular viewpoint in a static array” (Logie & Della Salla, 2005, p.84). Spatial refers to the “pathways or sequences of movements from one location to another in the scene, or the processes of change in the perceived relative locations of objects that occur when an observer moves from one viewpoint to another” (Logie & Della Salla, 2005, p.84). This movement can be a physical action, an adjustment to a mental image, or a combination (e.g. spatial-motoric output) (Pearson, De Beni, Cornoldi, 2001; Cornoldi & Vecchi, 2003; Logie & Della Salla, 2005; Kita, 2000). Typically developing children by approximately eight years of age are able to code distance and direction, use reference points to determine location, use hierarchal coding and categories to support processing of space and locations, mentally rotate objects, apply mapping skills, to take others perspectives, and to use language to convey and interpret spatial information (Newcomb & Learmouth, 2005).

Research has indicated that spatial ability including visual imagery is associated with proficiency in mathematics (Hegarty & Kozhevnikov, 1999; Ansari et al., 2003; Hegarty & Waller, 2006). The effective use of visual imagery enables students to create the schema to support problem solving in mathematics (Hegarty & Kozhevnikov, 1999). Also, efficient processing of visual-spatial information supports the understanding of numerical information such as cardinality and multiple forms of numerical representation (Ansari et al., 2003; Flevares & Perry, 2001; Geary, 2004). Often children affected by prenatal alcohol exposure exhibit deficits in visual-spatial skills that would impede their learning of mathematics (Kodituwakku, 2009).

Uecker and Nadel (1996) conducted a study to investigate the immediate and delayed recall of spatial information and the visual-motor integration to explore visual spatial processing in children with FAS. They compared children with FAS to a group of typically developing children. Using a Memory for Objects task to explore memory for spatial locations, Uecker and Nadel found that the children with FAS failed to recall the location and the arrangement of the objects. The results from the Memory for Objects task suggested that the ability to orient toward a target and the ability to form and maintain the spatial representation of a target could be impaired in children affected by prenatal alcohol exposure. The authors proposed that the children with FAS did not form mental representations to support their recall of the spatial relationships to complete the tasks (Uecker & Nadel, 1996).

To assess visual-spatial skills in children with FAS, the Beery-Buktenica Developmental Test of Visual Motor Integration (VMI) and a Clock Drawing Task were administered (Uecker & Nadel, 1996). These are paper and pencil tasks. The VMI required participants to copy a design from a given model. The Clock Drawing Task required the participants to recall the face of an analogue clock and to duplicate the clock from memory (Uecker & Nadel, 1996).

The children in the FAS group demonstrated difficulties copying the figures presented on the VMI as compared to the control group (Uecker & Nadel, 1996). Uecker and Nadel indicated that drawings by the children in the FAS group often presented distortions in the shape and orientation of the figure they were required to copy. Also, the authors indicated that the children in the FAS group would leave off details such as the corners of the designs (Uecker & Nadel, 1996). The findings suggested that children with FAS exhibited difficulties analyzing the spatial elements of a design to copy figures accurately (Uecker & Nadel, 1996).

The children with FAS also exhibited difficulties replicating the analogue clock from memory as compared to the control group (Uecker & Nadel, 1996). The children in the FAS group were directed to use language to help mediate their duplication of the clocks. The clocks duplicated by the FAS group displayed poor organization of the spatial layout (Uecker & Nadel, 1996). Based upon the results from the tasks, the investigators questioned whether the children with FAS were able to organize “the information in memory to duplicate the clock or if the children were unable to mark the spatial relationships needed to replicate the clock accurately” (Uecker & Nadel, 1996, p. 219). Uecker and Nadel suggested that the poor performance of the children in FAS group could be related to deficits visuo-spatial information to complete the motor tasks. Weaknesses with visual-motor integration have been found across studies investigating the neurological impairments associated with prenatal alcohol exposure (Roebuck-Spencer et al., 2004; Adnams et al., 2001). Deficits in processing visual-spatial information interfere with mathematics.

The next section presents the influences of the cognitive impairments associated with prenatal alcohol exposure and learning mathematics.

2.5 FETAL ALCOHOL SYNDROME AND MATHEMATICS

Mathematics requires the integration of verbal and visual information, efficient processing, and the ability to retain and manipulative visuo-spatial and numerical information in working memory. Studies have shown that the effects from prenatal alcohol exposure impair the cognitive processes needed to be proficient in mathematics (Jacobson et al., 2011; Burden, Jacobson, & Jacobson, 2005).

2.5.1 Numerical deficits

Compromises to the white matter as well as to the left superior and right inferior parietal regions and medial frontal gyrus of the brain are associated with the effects from prenatal alcohol exposure and interfere with the representation and manipulation of numerical information (Jacobson et al., 2011; Santhanam, et al., 2009). Due to the compromised brain structure and/or functions in these areas, many children with FAS exhibit deficits in estimation, understanding

number magnitude, applied arithmetic, and in mathematical reasoning (Jacobson et al., 2011; Santhanam et al., 2009; Howell et al., 2006; Kopera-Frye et al., 1996).

Jacobson, Dodge, Burden, Klorman, and Jacobson (2011) conducted a study investigating the differences in arithmetic skills of inner-city adolescents who had been affected by prenatal alcohol exposures as compared to inner-city adolescents who had a diagnosis of Attention Deficit-Hyperactivity Disorder (ADHD). Deficits in arithmetic are prevalent in children and adolescents with FAS as well as with a diagnosis of ADHD (Coles et al., 1997; Howell et al., 2006; Passolunghi, Marzocchi, & Fiorillo, 2005). However, Jacobson et al. (2011) suggested that the underlying causes of the difficulties with arithmetic were different between the two groups.

Jacobson et al. indicated that the problems with arithmetic displayed by adolescents with ADHD such as errors in exact and approximated calculation are explained by the global deficits with attention including inhibiting responses, problems attending to details, and difficulties with sustaining attention. The adolescents with FAS displayed difficulties in arithmetic due to deficits in mental representations of numerical amounts and comparing quantities (Jacobson et al., 2011). Deficits with mental representation and number magnitude are associated with numerical processing rather than functions of attention. Indications of a specific numerical processing deficit in adolescents affected by prenatal alcohol exposure are commensurate with the findings from previous studies (Jacobson, et al. 2011; Kopera-Frye et al., 1996).

Kopera-Frye, Dehaene, and Streissguth (1996) completed a study that indicated specific numerical processing deficits in adolescents and adults affected by prenatal alcohol exposure, the FAS-FAE group, compared to a control group of individuals without prenatal alcohol exposure. Eleven tasks were administered to the two groups to measure symbolic number processing, reading numbers, writing numbers, basic computation, and understanding number magnitudes. A cognitive estimation task also was administered to measure the participants' understanding of numerical quantities. The FAS-FAE group exhibited comparable performance on the number reading, number dictation, and the comparing number tasks to the control group. The FAS-FAE group did not perform as well as the control group on cognitive estimation task. The authors reported that the FAS-FAE participants could not generate numerical estimates to describe the height of a building (Kopera-Frye et al., 1996).

The findings from this study indicated that the FAS-FAE group exhibited preserved number comprehension as shown by their adequate performance on number reading and writing, but exhibited difficulties with estimating numerical information and in approximating calculations (Kopera-Frye et al., 1996). The authors suggested that selective impairments in estimation and approximation correlate with specific brain damage associated with prenatal alcohol exposure; this requires further empirical investigation. The difficulties processing numerical information would impact the foundations needed to understand higher order mathematics (Kopera-Frye et al., 1996; Geary, 2004).

2.5.2 Mathematics intervention program for children affected by prenatal alcohol exposure

Although studies have indicated that children with FAS exhibit deficits in processing numerical information, few studies have been conducted to investigate if children with FAS are able to make gains in learning mathematics when provided interventions. A recent study conducted by Kable, Coles, & Taddeo (2007) investigated the use of mediated learning experiences to increase thinking efficiency in children with FAS during mathematics instruction. The program developed by Kable, Coles, and Taddeo is called the Math Interactive Learning Experience (MILE). The study used scripted strategies and activities that presented a concrete demonstration of the skills and related concepts, guided practice, and mental management strategies to help children with FAS learn mathematics.

The findings from the studies indicated that children who participated in the MILE program demonstrated an increase in their overall mathematic achievement scores as well as improvements in their behavior in the classroom (Kable et al., 2007; Coles et al., 2009). However, analyses of the learning processes exhibited by the children with FAS who participated in the study to acquire a specific mathematical skill or concept were not reported (Kable et al., 2007). Publications regarding additional mathematical intervention programs designed for children with FAS were not found during the review of the literature for this dissertation.

2.5.3 Mathematics and gestures

The studies investigating mathematic difficulties associated with the effects from gestational alcohol exposure focusing on the processing of numerical information as measured by learning outcomes. However, the studies have not examined how children construct mathematic knowledge.

The coordination of gesture and speech is used to support efficient communication, assists the integration of information, and provides a visual display of thinking (Hostetter & Alibali, 2008; Hostetter et al., 2007). The use of gestures has been found play an active role in selecting strategies to solve problems (Alibali & Goldin-Meadow, 1993; Ping & Goldin-Meadow, 2008). Additionally, research has shown the children use gestures to facilitate learning equivalence. Given the cognitive impairments associated with the effects from prenatal alcohol exposure, it is not clear whether children with FAS would use gestures to support learning a mathematical concept.

A summary of the discussion from this chapter is presented in the following section.

2.6 SUMMARY OF CHAPTER TWO

A synopsis of the prevalence rate, the physical abnormalities, the cognitive impairments, and the secondary learning difficulties associated with the effects from prenatal alcohol exposure as discussed in this chapter is presented below.

- 1) The prevalence of children affected by prenatal alcohol exposure is estimated to be as high as 16.5 per 1,000 children in the United States to approximately 74.5 per 1,000 children in regions of South Africa (May et al., 2009; Viljoen et al., 2005). Determining the prevalence of FAS is confounded by variations in study methodology, by inconsistencies in diagnostic procedures, and by the cultural acceptance of alcohol use in the populations examined (Urban et al., 2008). Studies have shown that the prevalence of FAS continues to be as high as or higher than the prevalence of other developmental disabilities and continues to be a pervasive problem in the United States, South Africa, and in other nations (Bertrand et al., 2004).

- 2) The effects from prenatal alcohol exposure cause a range of physical and cognitive abnormalities that overlap with other developmental disabilities (Bertrand et al., 2004; Kable & Coles, 2004a). The evaluation for a FAS diagnosis requires an interdisciplinary team who is trained to differentiate the characteristics associated with the effects from prenatal alcohol exposure from other developmental disorders (Bertrand et al., 2004). An accurate diagnosis of FAS is necessary to ensure that children affected by prenatal alcohol exposure receive interventions designed to address their cognitive deficits and learning needs (Kable & Coles, 2004a).
- 3) The cardinal physical features and cognitive impairments associated with effects from prenatal alcohol exposure are as follows:
 - a) Prenatal alcohol exposure is associated with delays in growth and facial dysmorphism that includes 1) smooth philtrum, 2) thin vermilion border of the upper lip, and 3) shortened palpebral fissures. Also, microcephaly, an abnormally small head circumference, is linked to the effects from prenatal alcohol exposure (Astley, 2004; Bertrand et al., 2004).
 - b) Damage to brain structures such as but not limited to the corpus callosum, the loss of white matter integrity, and compromises to the parietal region are associated to the effects from prenatal alcohol exposure (Ma et al., 2005; Lebel et al., 2008; Jacobson et al., 2011). The abnormalities of the corpus callosum and loss of white matter in other brain regions hinder the efficient speed of processing and integration of verbal and visual information (Ma et al., 2005; Burden, Jacobson, & Jacobson, 2005). Damage to parietal region of the brain is associated with problems determining number magnitude and estimating amounts (Santhanam et al., 2009; Wozinak & Meutzler, 2011; Jacobson et al., 2011).
 - c) The cognitive impairments associated to the effects from prenatal alcohol exposure range from low intellectual functioning to specific deficits in encoding, speed of processing, working memory, attention and executive functioning. Also, deficits with visuo-spatial processing and integrating verbal and visual information are attributed to the effects from prenatal alcohol exposure (Kodituwakku, 2009; Mattson et al.,

2006; Uecker & Nadel, 1996; Ma et al., 2005). Problems with these cognitive processes hinder learning.

- 4) Due to the compromises to cognitive functions, many children diagnosed with FAS exhibit secondary learning disorders, most notably in mathematics (Kable et al., 2007; Kable & Coles, 2004a). The Mile Interactive Learning Experience (MILE) program used scripted strategies, provided concrete demonstration of skills and concepts, and taught children with FAS how to use mental management strategies to learn mathematics (Kable et al., 2007; Coles et al., 2009; Bertrand, 2009). The children who participated in the MILE program made improvements in their scores on a mathematical achievement test (Kable et al., 2007). However, it is not clear how children with FAS construct the understanding of mathematics or if their cognitive processes were changed through the interventions provided through the program.

The importance for studying the use of gestures while learning mathematics in children is discussed in the next chapter.

CHAPTER THREE

GESTURES, LEARNING, AND MATHEMATICS

3.1 INTRODUCTION

As discussed in chapter two, children affected by prenatal alcohol exposure often exhibit impairments integrating visual and verbal information, display deficits with encoding, and have problems manipulating visual-spatial information. These deficits interfere with learning mathematics. The studies investigating mathematic deficits in children with FAS have focused on overall performance rather than the learning of a specific skill or concept (Kable et al., 2007). The present study attempts to expand the research about the mathematical deficits associated with the effects from prenatal alcohol exposure by investigating gesture use in children affected by prenatal alcohol exposure as they learn a specific mathematic concept.

Gestures have been found to serve multiple functions during interpersonal exchanges and learning mathematics (Alibali & Goldin-Meadow, 1993; Rauscher, Krauss, & Chen, 1996; Krauss, Dushay, Chen, & Rauscher, 1995; Krauss, 1998; Emmory & Casey, 2001; Kita, 2000). Gestures are defined as spontaneous movements, coordinated with speech, that do not have a “pre-established form-meaning relationship; their meaning is determined on-line with each performance” (Ozyurek, 2000, p. 67; McNeill, 1992). Research has suggested that gesturing assists with the integration of verbal and visual information and representation of visual-spatial information that cannot be verbalized easily (Goldin-Meadow, 1999).

Studies have shown that gestures facilitate cognitive organization and concept formation (Alibali, 2005; Kita, 2000). The various functions of gestures have been found to support integration of verbal and visual, transitions in learning, encoding, and assist in rehearsing information in working memory for further processing (Kita, 2000; Alibali & Goldin-Meadow, 1993; Goldin-Meadow, Cook, & Mitchell, 2009). Deficits in these areas are associated with the effects from prenatal alcohol exposure however minimal research has been conducted to investigate the uses of gestures in children with FAS (Millians et al., 2007).

Chapter three discusses the rationale for investigating gesturing in children affected by prenatal alcohol exposure. This chapter reviews the current literature on the uses of gestures by children with and without developmental disabilities as well as the functions of gesture use to learn mathematics.

3.2 GESTURES

Gestures are spontaneous movements often co-occurring with speech to convey information and support cognitive processes (McNeill 1992). Researchers debate whether gestures are an internal process used to assist the speaker's retrieval of information, whether gestures are an externalized function used to express ideas, or whether gestures contribute to concept formation and the organization of thought (McNeill, 2005; Rauscher et al., 1996; Kita, 2000).

3.2.1 Gesture theory

Two theories on the uses of gestures to support the expression of ideas are the Lexical Retrieval Hypothesis and the image activation theory (Rauscher et al., 1996; Krauss et al., 1995; Krauss, 1998; Emmory & Casey, 2001). The Lexical Retrieval Hypothesis proposes that gestures assist the speaker's retrieval of ideas and words during interpersonal exchanges. The image activation theory suggests the use of gestures aid in the translation of an internal image into a linguistic format for verbal expression (Kita, 2000; Feyereisen, 2006; McNeill, 2005; Emmory & Casey, 2001). Critics argue that these theories overlook the influence of gestures on concept formation and organization of thought (Kita, 2000; Alibali, 2005).

Sotaro Kita (2000) proposed in the Information Packaging Hypothesis that gestures are used to process information as well as to support with the expression of ideas. Kita (2000) suggested that speech and gesture are two independent systems that become highly coordinated around a common organizational goal. Kita (2000) indicated that representational gestures are used to combine spatio-motoric information into units that are arranged and integrated to form concepts. The packaging of spatio-motoric information into units allows individuals to access thinking in various forms and increases cognitive flexibility (Kita, 2000). According to the Information Packaging Hypothesis, the coordination of speech and gestures, displays the unification of thinking through the alignment of mental imagery represented by gestures with the linear

composition of speech (Alibali, Kita, & Young, 2000). The integration of spatio-motoric and linguistic information enables a speaker to convey a complete message.

Alibali, Kita, and Young (2000) conducted a study to gather empirical evidence to support the Information Packaging Hypothesis. The study investigated children's learning about conservation using liquids and different sized containers. The purpose of the study was to explore whether gesture assisted the integration of spatial-motoric information to support conceptual planning or whether gestures were used only to express ideas.

In the study, children produced more substantive gestures, illustrating a dimension of an object through the shape of their hands or by their movement, as they explained how they solved the problem than when they provided a description of the task. The authors suggested the children's use of gestures increased when visual-spatial information needed to be organized and integrated into thought processes and expressed in language. The findings from the analysis of children's gesturing as they explained their solutions during the conservation task was compatible with the premise of the Information Packing Hypothesis stating that gesture facilitates the processes of thinking, organizing, as well as assisting with expressing complex thoughts as (Alibali et al., 2000).

Hostetter, Alibali, and Kita (2007) conducted a study to investigate the Information Packaging Hypothesis in relation to the use of gestures to conceptualize and organize information for speaking. The study required participants to describe ambiguous patterns that consisted of dots or a combination of dots and shapes. The results indicated that the participants used a higher rate of representational gestures to describe the dot-only patterns as compared to the patterns that combined dots with shapes. The authors surmised that the dot only patterns were more difficult to conceptualize and required the participants to use gestures to organize the visuo-spatial information while verbalizing their descriptions. The researchers concluded that an increase of gestures was found when information was difficult to conceptualize and organize into units for further processing (Hostetter et al., 2007).

Studies have shown the gestures are used not only to support concept formation as indicated through the Information Packaging Hypothesis but also assist in the transformation of thoughts. Also, research has indicated that children's use of gestures gives insight into children's readiness to learn and support the rehearsal of information or further processing in working

memory (Perry et al., 1988; Alibali & Goldin-Meadow, 1993; McNeil & Alibali, 2004; Goldin-Meadow et al., 2009). The following section reviews the literature about the impact of gestures on transition of thought, working memory, and encoding while children learn the mathematical concept of equivalence.

3.3 GESTURES AND LEARNING MATHEMATICS

Mathematical proficiency requires the skills to generate accurate mental representations of a problem, to select effective strategies and procedures to solve problems, to apply problem solving techniques across contexts, and to understand the usefulness of mathematics (Kilpatrick, et al 2001). This includes the efficient integration of conceptual and procedural knowledge to be successful in solving mathematical problems (Rittle-Johnson, Siegler, & Alibali, 2001; Kilpatrick et al., 2001).

Studies have shown that children's use of gestures while learning mathematics provides insight into their transformation of knowledge and their readiness to receive instruction (Perry et al., 1988; Alibali & Goldin-Meadow, 1993). Also, gestures aid in the rehearsal of information in working memory for additional processing (Goldin-Meadow, Cook, & Mitchell, 2009). The studies reviewed in this section focus on the impact of children's gesture use while learning and applying the concept of equivalence to solve problems (Perry et al., 1988; Perry, Breckinridge Church, & Goldin-Meadow, 1992; Alibali & Goldin-Meadow, 1993; Goldin-Meadow et al., 2009).

3.3.1 Gestures as transitions of thought

According to Perry, Breckinridge Church, and Goldin-Meadow (1992) different messages conveyed through speech and gesture indicate the activation of more than one notion and signify transitions in learning. To investigate if gesturing marks transitions in learning, Alibali and Goldin-Meadow (1993) conducted a study examining children's uses of gestures as they progress from an incorrect understanding of equivalence to an accurate understanding. The definition of equivalence was not defined clearly in the study. However, the instruction provided to the children to solve addition problems required them to make each side of the equation, separated by an equals sign, the same amount. This reflected the concept of equivalence as meaning the same as (Alibali & Goldin-Meadow, 1993).

The study required children in the fourth grade to learn to solve equivalence problems that used the formats of 1) $a + b + c = _ + c$, 2) $a + b + c = _ + d$, and 3) $a \times b \times c = _ \times c$. The children completed a paper and pencil pretest as well as solved and explained a problem in order to evaluate their understanding of equivalence. Next, the children were divided into one of three groups before participating in the training activity. The groups were 1) No Instruction, 2) Addition, and 3) Addition-plus-Multiplication. Children in the No Instruction group solved and explained twelve addition problems, six that followed the format of $a + b + c = _ + a$, and six that followed the format of $a + b + c = _ + d$. The children in the No Instruction group did not receive feedback or instruction as to how to solve the problems. The children in the Addition group solved the same problems as the children in the No Instruction group but were provided feedback and instruction on ways to solve the addition problems.

The children in the Addition-plus-Multiplication group solved the same problems as the No Instruction and the Addition groups. Furthermore, they solved six multiplication problems that followed the format $a \times b \times c = _ \times c$ (Alibali & Goldin-Meadow, 1993). The children in the Addition-plus-Multiplication group received instruction and feedback on solving the addition problems and generalizing the concept of equivalence to solve the multiplication problems. After the training sessions, the children in each of the groups were administered a paper-and-pencil-post test. A follow-up paper-and-pencil test was administered two weeks after completing the study activities (Alibali & Goldin-Meadow, 1993)

The children's use of speech and gestures to explain how they solved the problems during the pre-test and the training activity were transcribed and coded. The coded gestures were categorized as either discordant, presenting messages in speech that were different from the messages presented in gesture, or concordant where the messages presented in speech and gesture were the same. The children's use of concordant and discordant gestures during the pretest and the training activity were examined in relation to their mastering their concept of equivalence as shown by their performance on the post-test and the follow-up test (Alibali & Goldin-Meadow, 1993).

Alibali and Goldin-Meadow (1993) defined four possible paths children would follow to learn equivalence: 1) Progression through a discordant state in which children's initial understanding of equivalence was represented through incorrect concordant gestures, moved into a discordant before entering a correct concordant state. 2) Progression without moving through a discordant

state in which children's initial understanding of equivalence was represented by incorrect concordant gestures and move directly to a correct concordant state. 3) Regression during training in which children move from a correct concordant state into either a discordant state or into an incorrect concordant state. 4) Staying in the same state in which the children exhibited no change in the understanding of equivalence (Alibali & Goldin-Meadow, 1993).

The results from study indicated that children in the No Instruction group were more likely to stay in the same state or to regress as compared to children who received instruction. Also, children who did not receive instruction were less likely to move through a discordant state to a correct concordant state while learning equivalence. Few children showed minimal progress learning about equivalence in either of the instructional groups or in the No Instruction group without passing through a discordant state. Alibali and Goldin-Meadow (1993) suggested that the children who passed over the discordant state may have acquired a superficial understanding of equivalence by discarding an older strategy and adopting the new one without integrating to build upon previous knowledge.

Children who learned to solve the equivalence problems correctly began with a single inaccurate hypotheses on solving problems, move toward incorporating new information as they received instruction about equivalence displayed through discordant gestures, and progress to a concordant correct state once they have mastered the concept and knowledge has stabilized (Alibali & Goldin-Meadow, 1993).

According to Alibali and Goldin-Meadow (1993) discordant gestures provide insight into a child's "concurrent activation of multiple hypothesis and is a feature of the internal conceptual organization which characterizes the transitional knowledge state" (p.509). The authors noted that the children who passed through a discordant phase during the learning process were able to generalize the knowledge more efficiently than the children who did not transition through the discordant state. They suggested that the mismatch between the child's gestures and speech indicate the beginnings of the re-description process and deeper learning (Alibali & Goldin-Meadow, 1993; Karmiloff-Smith, 1992).

3.3.2 Gestures and the readiness to learn

Perry, Breckinridge Church, and Goldin-Meadow (1992) suggested that children who exhibit many discordant gestures would be open to learning due to their transitional state of understanding. Perry, Breckinridge Church, and Goldin-Meadow (1988) examined whether children who showed an increase of discordant gestures would benefit from instruction as compared to children who conveyed similar messages in speech and gesture. Children who exhibited discordant gestures were provided instruction that either focused on the concept of equivalence or focused on the procedures to solve addition problems using the associative property of addition. After receiving instruction, the children were asked to solve problems that expanded on the original problem format of $a + b + c = a + \underline{\quad}$. Examples of the addition and multiplication problems used to assess generalization followed the formats of $a + b + c = d + \underline{\quad}$ and $a \times b \times c = a \times \underline{\quad}$ (Perry et al., 1988).

Children who received instruction focusing on the concept of equivalence showed an increase in their skills to solve the generalization problems correctly. The control group that received instruction on the procedure was unable to generalize the information to solve the novel addition problems and the multiplication problems (Perry et al., 1988). The findings suggest that gestures provided insight into the readiness to learn a concept as well as the transition of learning.

Subsequent research has shown that encouraging children to gesture during the learning process may increase thought transition and new learning. In 2007, Broaders, Cook, Mitchell, and Goldin-Meadow investigated whether gestures tapped into children's implicit knowledge and whether requiring children to gesture would improve their learning of the concept of equivalence. The children in the study were required to solve for missing addends in an equivalence problem, such as in the problem $5 + 3 + 4 = \underline{\quad} + 4$.

Broaders et al. examined whether encouraging children to gesture would prepare them to receive instruction. The children were placed into either the "told not to gesture group" or the "told to gesture" group. The children completed a paper-and-pencil pretest solving equivalence problems that followed the same format as in study one. Then, children were asked to solve and explain six problems presented on a board. The children were told to either gesture as they explained their answers or not to gesture depending upon their group. Next, solving the problems, the children in each group watched and listened to a lesson on equivalence solving

problems that followed the same format. After the lesson, the children completed a paper-and-pencil post-test. The findings indicated that the children in the “told to gesture” group increased their strategies to solve the equivalence problems and solve more problems correctly than the children in the “told not to gesture” group. The authors noted that changes in the children’s implicit understanding affected the changes in learning. They concluded that encouraging children to gesture during the learning process brings forth implicit knowledge that is formed into new strategies to facilitate the learning process (Broaders et al., 2007).

3.3.3 Gestures and encoding

Mathematic programs in most elementary and middle schools in the United State are based on the premise that proficiency in basic skills is necessary for higher level mathematical thinking (McNeil & Alibali, 2004). Often basic skill instruction entails extended lessons and practice in arithmetic before introduction to solving complex problems (McNeil & Alibali, 2004). The over-learning of common arithmetic problem patterns may hinder the encoding of new problems that do not conform to the familiar patterns. The focus on computation and limited exposure to novel or complex equations influences children’s interpretation of the equals sign. Children from elementary school into high school often misinterpret the equals sign as an operational symbol indicating the answer to a problem rather than representing a similar relationship between amounts (Seo & Ginsburg, 2003; McNeil & Alibali, 2004; Kieran, 1981; McNeil & Alibali, 2005).

McNeil and Alibali (2004) investigated individual differences in encoding, in strategy use, and in the understanding of equivalence in fourth grade students. The children were required to solve and explain common addition problems (e.g. $5 + 4 + 9 + 5 = \underline{\quad}$) and equivalence problems (e.g. final blank: $4 + 3 + 6 = 4 + \underline{\quad}$ or initial blank: $6 + 4 + 5 = \underline{\quad} + 5$). The children’s explanations were videotaped and their gestures were coded and analyzed to infer their use of problem solving strategies. The encoding task required the children to view addition and equivalence problems one at a time and recreate the problems on a black board.

The results indicated there is a relationship between children’s strategy and encoding. Encoding as defined by McNeil and Alibali (2004) referred to the mental representation of the salient features of a problem. The study found that children whose gestures indicated an “add-all” strategy to solve problems frequently encoded the equivalence problems as common addition problems. The children encoded the numbers in the problem accurately but overlooked the

structure of the problem. McNeil & Alibali (2004) indicated this was due to high exposure to common addition problems. Also, children who relied on the “add-all” strategy exhibited a higher amount of conceptual errors than the children who used an accurate strategy but calculated the problem incorrectly and the children who used other incorrect strategies. The results indicated that children who considered more than one problem solving strategy exhibited through their gesture and speech made fewer errors in encoding the structure of the problem.

McNeil and Alibali (2004) concluded that encoding of problems directs the use of procedures to solve problems however prior knowledge interferes with accurate encoding and problem solving. The analysis of gestures enabled the researchers to determine the types of strategies in the children’s repertoire in order to determine their patterns in encoding problem features.

3.3.4 Gestures and memory

Cook, Mitchell, and Goldin-Meadow (2008) investigated the use of gestures by children in the third and fourth grades and their retention of a mathematical strategy to solve an equivalence problem that followed the format of $4 + 9 + 3 = 4 + \underline{\quad}$. The children were administered a paper-and-pencil pre-test requiring them to solve equivalence problems and asked to explain their solutions. Children who did not answer any of the questions correctly and/or provide accurate explanations on the pretest were included in the study. Next, the children were provided instruction on a strategy to solve the equivalence problem. The children were taught the “equalizer strategy” using speech and gesture that conveyed the same message. The instructor used a sweeping motion with the left hand under the left side of the equation and a sweeping motion with the right hand under the right side while stating that one side of the equation is to be equal to the other side. Children were provided six instructional examples using the strategy. The children were asked to solve and explain their solution to a similar problem using either speech only, gesture only, or speech and gesture. A post-test was administered after the children solved the problems. In addition, a follow-up test was administered approximately four weeks to investigate retention of information.

The results indicated that the children in the gesture only and the speech and gesture groups showed significantly more retention of information as compared to the speech only condition (Cook et al., 2008). The authors suggested that the use of a verbal script to retain information

did not support consolidation and recall of information after four weeks. The children who used gestures were able to solve the equivalence problems accurately after four weeks.

Cook, Mitchell, & Goldin-Meadow (2008) indicated the findings from the study supported the premise that gestures aid in the retention of information but did not state how this occurred. The authors proposed several factors on ways gestures support learning. The authors suggested that pointing gestures might support learning by drawing attention to relevant information. They proposed that gestures assist in the integration of information. Also, they indicated that gestures provide a spatio-motoric representation of the information to support rehearsal, encoding, and registration in memory.

Studies have shown the gestures serve multiple functions in expressing ideas, integrating information, and learning, especially mathematics. The various uses of gestures to support communication and thought transitions are demonstrated further through the gesture use by children with developmental disabilities. This is discussed in the following section.

3.4 GESTURE USE BY CHILDREN WITH DEVELOPMENTAL DISABILITIES

Gesture use has been studied in children with Down syndrome, Developmental Coordination Disorder, lesions in the right and left hemispheres of the brain, and with Williams syndrome. Though the etiologies of these disorders differ, they exhibit cognitive impairments that are associated with the effects from prenatal alcohol exposure (Bertrand et al., 2004).

3.4.1 Gesture use by children with Down syndrome

Studies have investigated spontaneous gesture use in children with Down syndrome. Down syndrome is a genetic disorder caused by a trisomy on a large portion or all of chromosome 21. According to the information provided by the Online Mendelian Inheritance in Man, a database on human genetics and disorders developed by McKusick and others from Johns Hopkins University and the National Center for Biotechnology Information, trisomy on chromosome 21 related to Down syndrome causes mental retardation, congenital heart malformations, and physical and facial alterations. Conductive hearing loss, language, and articulation difficulties

also are common in children with Down syndrome (<http://www.ncbi.nlm.nih.gov/omim/190685>, Retrieved: 1 May 2010).

Caselli, Vicari, Lomgobardi, Lami, Pizzoli, and Stella (1998) studied gesture use in children with Down syndrome as compared to a control group of typically developing children. The results showed that children with Down syndrome used gestures to communicate information that was more sophisticated than they were able to articulate. Caselli et al. found that children with Down syndrome increased their gesture use when expressing information that contained symbolic, imaginative, and transformative messages. The authors suggested that the increase in gesturing in children with Down syndrome occurred when the expression of conceptual and spatial information became challenging due to articulation difficulties.

3.4.2 Gesture use by children with developmental coordination disorder

Unlike children with Down syndrome whose gesturing assists with language output, children with Developmental Coordination Disorder did not use gesture to convey information or to organize thoughts. Developmental Coordination Disorder is characterized by “difficulties performing age appropriate, skilled motor movements” (Accardo & Whitman, 2002, p.114). Motor difficulties associated with Developmental Coordination Disorder are considered to be a result of abnormalities in neurotransmitters or receptor systems and not necessarily damage to specific neurons or brain structures (Barnhart, Davenport, Epps, & Nordquist, 2003). In 2002, Zoia, Pelamatti, Cuttini, Casotto, and Scabar conducted a study that compared gesture use in children ages five to ten years old with Developmental Coordination Disorder to typically developing peers to investigate the impact of motor movements on thinking processes.

The findings from the Zoia et al. study showed that children with Developmental Coordination Disorder were able to imitate a manual movement and respond to a visual prompt using a simple manual movement, such as pointing. The findings indicated that children with Developmental Coordination Disorder did not use gestures to support the integration of verbal and visual information. Zoia et al. proposed that the information needed to imitate or to provide a simple pointing response was easier to encode as compared to tasks that required the integration of information to formulate a response using a representative gesture. The authors surmised that the poor gesturing responses by the children with Developmental Coordination Disorder suggested difficulties with integrating the information from the sensory system into motor

representations (Zoja et al., 2002). The findings were similar to the results from an earlier study investigating motor planning and visual-spatial imagery conducted by Wilson, Maruff, Ives and Currie (2001). Wilson, Maruff, and Ives (2001) suggested that children with Developmental Coordination Disorder had difficulties generating images to support organization and sequencing of motor movements.

3.4.3 Gesture use by children with hemispheric brain lesions

Children with lesions on the right hemisphere of the brain were found to use minimal gestures during communicative tasks. Meanwell, Simone, and Levine (2006) conducted a study comparing gesture use in young children with lesions on the right and the left hemispheres of the brain. The results suggested that young children with lesions on the right hemisphere of the brain produced a lower proportion of utterances with gestures as compared to typically developing children. Unlike the children with right hemisphere lesions, the young children with left hemisphere lesions demonstrated a gesture and utterance pattern similar to children who exhibited a normal developmental profile. The authors suggested that the lack of gestures to integrate information and to facilitate communication in children with lesions to the right hemisphere was due to the location of the lesions (Meanwell et al., 2006).

The findings from the studies investigating gesture use in children with Developmental Coordination Disorder and with brain lesions suggest that difficulties with the use of gestures to integrate information may be influenced by problems in neurotransmitters, receptor systems including white matter of the brain, or damage to specific structures or locations of the brain (Zoja et al., 2002; Meanwell et al., 2006).

3.4.4 Gesture use by children with Williams syndrome

Studies have been conducted to investigate gesture use in children with Williams syndrome. Williams syndrome is a rare genetic disorder caused by a microdeletion on chromosome 7, band 7q11.23. The deficits associated with Williams syndrome include impaired to below average range of intellectual functioning, deficits in processing visual-spatial information, and impairments with visual-motor integration and motor coordination (Korenberg et al., 2001; Nakamura et al., 2001; Jarrold et al., 1998). The cognitive impairments associated with Williams syndrome share similar characteristics as those associated with the effects from prenatal alcohol exposure (Korenberg et al., 2001; Bertrand et al., 2004).

Like children with FAS, children with Williams syndrome exhibit inconsistent patterns of language development and usage (Nazzi, Gopnik, & Karmiloff-Smith, 2005; Mervis & Bertrand, 1997). Vocabulary recognition appears to be a relative strength in children with Williams syndrome. In some cases, vocabulary knowledge has been found to be comparable to age matched peers despite other cognitive deficiencies (Jarrold et al., 1998). Though vocabulary knowledge has been shown to be a relative strength, research has suggested that children with Williams syndrome often select unusual or inaccurate words to express their ideas during interpersonal exchanges.

A study conducted by Stojanovik (2006) found that children with Williams syndrome demonstrated an understanding of the conventions of interpersonal exchanges but provided verbal responses disconnected from the conversational topic. Other studies have shown that children with Williams syndrome have difficulties interpreting the subtle nuances of language and nonverbal forms of communication including gestures (Karmiloff-Smith et al., 1997; Laing et al., 2002; Mervis, & Bertrand, 1997; Stojanovik, 2006).

Bello, Capirci, and Volterra (2004) conducted a study to investigate lexical production of children ages nine to twelve years old with Williams syndrome. The results from the study showed that children with Williams syndrome used gestures to facilitate word retrieval but not to represent ideas. Furthermore, studies have found that young children with Williams syndrome showed minimal gesture use when learning language as compared to typically developing age-matched peers.

Mervis and Bertrand (1997) explored the language development in young children with Williams syndrome. They found that toddlers with Williams syndrome use words to refer to objects before “either producing comprehending or pointing gesture” (Mervis & Bertrand, 1997, p. 89). Research into early language development has indicated that gesture and language production in young children generally coincide. This suggested that children with Williams syndrome exhibit an atypical developmental trajectory for language (Karmiloff-Smith et al., 1997; Mervis & Bertrand, 1997).

Other studies investigating nonverbal communication skills in children with Williams syndrome have found minimal use and awareness of gestures during interpersonal exchanges. Laing, Butterworth, Ansari, Gsodl, Longhi, Panagiotaki, Paterson, and Karmiloff-Smith (2002) investigated the social communication skills in toddlers with Williams syndrome. The findings from their study showed that young children with Williams syndrome did not attend to or use pointing to direct or elicit attention during communication exchanges among three or more participants. The authors proposed that the children with Williams syndrome perceived an interpersonal exchange was occurring but had difficulty understanding the subtle meanings presented in modalities other than speech (Laing et al., 2002; Stojanovik, 2006; Mervis & Bertrand, 1997).

The differences in gesture use among children with developmental and genetic disorders reflect the variety of uses of gestures. Children with Developmental Coordination Disorder and lesions to the right hemisphere of the brain did not use gestures to support the transformation of stimuli into other formats to convey their ideas. Children with Williams syndrome use gestures to support lexical access to information, while children with Down syndrome use gestures to present information that could not be verbalized due to difficulties with language processing and articulation. Because of the variation in the uses of gestures among populations with developmental disabilities, a general pattern of gesture cannot be defined. The impact of gestures on learning and expressing ideas would need to be investigated in relation to a targeted population.

3.4.5 Language, gestures, and children with fetal alcohol syndrome

Research has been inconclusive determining whether reported language difficulties are a direct result of maternal alcohol consumption during pregnancy. Like children with Williams syndrome, children with FAS may exhibit relative strengths in identifying vocabulary relative to skills that require the integration of visual-spatial information to form abstract linguistic concepts (Coggins, Freit, & Morgan, 1998; Becker, Warr-Leeper, & Leeper, 1990; Uecker & Nadel, 1996). Some studies have shown that children affected by prenatal alcohol exposure exhibit difficulties organizing verbal information and understanding the nuances of language used during interpersonal exchanges.

Thomas (1996) completed a study exploring the social and perspective taking skills in children with Fetal Alcohol Syndrome (FAS). The findings suggested that children with FAS showed impaired interpersonal skills. The children with FAS presented deficits in their ability to interpret the implicit messages that often underlie social exchanges. Like the children with Williams syndrome, the children with FAS were able to follow the conventions of a social exchange such as taking turns but were unable to take the other's social perspective (Thomas, 1996). However, the influence of nonverbal cues on interpreting another's mindset during interpersonal exchanges was not addressed in Thomas' study.

Coggins, Freit, and Morgan (1998) conducted a study to explore the skills to narrate a story in adolescents with FAS. The study investigated the use of narrative productions as a method to assess language and social communication in adolescents diagnosed with FAS. Using a book that contained only pictures that depicted a story of a boy and a frog, the adolescents were required to review the book, and to create a story that related the events depicted in the picture book. The authors found that the adolescents with FAS described the details of the pictures but constructed narratives that lacked logical structure and pertinent information. They suggested the disjointed telling of a story was related to their difficulties with encoding and processing the stimuli rather than a specific language deficit (Coggins et al., 1998; Becker et al., 1990). Difficulties with organization of narratives would negatively affect social interactions and academic performance. Studies investigating language use in children and adolescents with FAS have focused on verbal communication with minimal attention to the impact of nonverbal forms of communication, such as gesturing during interpersonal exchanges.

As indicated in chapter one, Millians, Coles, and Michener (2007) conducted a case study investigating the gesture use of a child with FAS as compared to a child with Attention Deficit-Hyperactivity Disorder (ADHD), and a child who did not have a clinical diagnosis. After counting and categorizing gestures used by each child while completing an etch-a-sketch design of a house in collaboration with their caregiver, the child with FAS used as many gestures as the child with ADHD. The children with FAS and ADHD used more gestures than the child without a clinical diagnosis. The child with ADHD and the child without a clinical diagnosis used gestures to represent elements of the house however the child with FAS did not. Though information from the case study cannot be generalized to a larger population, it suggested a possible difference in the use of gestures to convey information in a child with FAS.

A defined pattern of gesture use cannot be determined in children with developmental disabilities or genetic disorders, including FAS (Caselli et al, 1998). This study is an attempt to investigate whether children affected by prenatal alcohol exposure use gestures to learn the mathematical concept of equivalence. The following section discusses the theoretical basis selected to code and analyze gestures to assess children's learning of equivalence for this study.

3.5 ASSESSING LEARNING THROUGH GESTURES

This study is based upon the previous work of Alibali and Goldin-Meadow (1993) and the work of Perry, Breckinridge Church, and Goldin-Meadow (1998) that investigated children use of gestures as they transitioned thoughts to form new knowledge. Alibali and Goldin-Meadow (1993) indicated that gestures assist in the redescription of information to support encoding. Also, gestures provide a display of the integration of spatio-motoric information as outlined in the Information Packaging Hypothesis. Given the deficits associated with the effects from prenatal alcohol it is possible that children with FAS exhibit minimal gestures to integrate information and support learning.

Analyzing children's use of gesture using the Information Packaging Hypothesis in combination with the Representational Redescription (RR) model would provide educators a method to use gesture analysis to determine children's level of understanding during the learning process (Kita, 2000; Hostetter et al., 2007; Karmiloff-Smith, 1992). The Representational Redescription (RR)

model (Karmiloff-Smith, 1992) attempts to describe the manner in which children's thinking becomes more flexible. The RR model counters an incremental perspective of learning and views learning as cyclical frequent transformations of thought (Karmiloff-Smith, 1992). Developmental stages tend to focus on the outcomes without distinguishing the child's level of behavior mastery, or the stability of their knowledge (Karmiloff-Smith, 1992). The focus on outcomes may lead instructors to misinterpret the children's level of understanding, especially in mathematics that often require rote procedures to complete problems (Karmiloff-Smith, 1992; Pine & Messer, 1999).

3.5.1 Representational redescription model

According to the RR model, knowledge transforms in phases from implicit retention to explicit understanding that is expressed in language (Karmiloff-Smith, 1992). The RR model proposes three recurrent phases to describe the learning processes. These phases can occur simultaneously, at different levels, and across learning domains. During the first phase, information is encoded as separate procedures. Information during the first phase is remembered as sequential steps and is stored in isolated elements linked to previous knowledge. The isolated components of a concept, separated from stable knowledge are defined as the "microdomains" (Karmiloff-Smith, 1992, p.19). Through external experiences, children begin to make connections with information stored during the first phase. The information gathered during the first stage is integrated into previous knowledge during the second phase. However, some information remains static at the first phase and is used to complete automatic or rote memory tasks. Observation of children's gestures provides insight into the state or level of their thinking processes (Perry et al., 1992). For example, in the 1988 study conducted by Perry, Breckinridge Church and Goldin-Meadow, children who conveyed the same messages in gestures and speech or who did not use gestures to present their understanding of equivalence, did not benefit from instruction as compared to children who exhibited mismatches in speech and gestures. This suggested that the children's understanding of the concept was static or stabilized.

During the second phase of the RR model, children have started to transition the information stored in the microdomain. The information in the microdomain dominates new incoming information as children transition the information to the next phase. The transition requires the information to be encoded into a different format for use (Karmiloff-Smith, 1992). The transitions

of thought are observed through children's uses of gestures and speech (Perry et al., 1988; Alibali & Goldin-Meadow, 1993; Hostetter et al., 2007). For example, Alibali and Goldin-Meadow (1993) found that children who showed discordant gestures as they learned about equivalence had activated more than one strategy. Through practice and instruction children stabilized their knowledge as demonstrated through concordant correct gestures and accurate explanations (Alibali & Goldin-Meadow, 1993).

By the third phase, according to the RR model, knowledge has been transformed into different formats that can be accessible across systems. Children's knowledge at this level has been stabilized and can be conveyed to others through language. The RR model implies that learning constantly overlaps and occurs across levels. The goal of learning is to develop behavioral mastery, or to stabilize knowledge, in order to create the foundations to support new learning (Karmiloff-Smith, 1992).

The RR model considers more than the accuracy of a response and attempts to identify "when a child may be particularly receptive to, or resistant to, teaching" (Pine & Messer, 1999, p. 30). Alibali and Goldin-Meadow (1993) observed children's learning trajectory to solve equivalence problems through their gestures. The authors found that children started at an incorrect concordant state, progress into a discordant state, and returned to a concordant state that was correct. The correct concordant state suggested that children had mastered the concept and their knowledge had stabilized (Alibali & Goldin-Meadow, 1993). This is an ongoing process as children learn new information and build upon previous knowledge.

3.5.2 Gesture analysis, representational redescription model and learning

Mathematics requires the integration of verbal, spatial, and symbolic information. Analyzing the coordination of gesture and speech through the Information Packaging Hypothesis would provide a view into children's cognitive changes as they learn a mathematical concept. According to the Information Packaging Hypothesis, gestures assist with the transformation of spatio-motoric information into other forms (Kita, 2000). Observing and analyzing the coordination of children's gestures and speech using the Information Packaging Hypothesis would enable instructors to ascertain information about their transitions of thoughts and formation of concepts as they learn mathematics (Hostetter et al., 2007). Applying the results from the gesture analysis into the RR model would enable instructors to determine the children's

level or state of learning. This would provide the information needed to adjust instruction during the learning processes.

This study is to investigate the uses of gestures by children affected by prenatal alcohol exposure as they learn the concept of equivalence. The study is based upon the previous work conducted by Perry et al. (1988), Alibali and Goldin-Meadow, (1993), and Hostetter, et al. (2007). This study entails the use of the Information Packaging Hypothesis to analyze children's gesture and to apply the results into the RR model to investing learning.

A summation of the discussion of gestures and learning in this chapter is presented in the following section.

3.6 SUMMARY OF CHAPTER THREE

A synopsis of the influence of gesture use on learning is presented below.

- 1) Gestures are defined in the study as spontaneous movements that coordinate with speech to present a complete message that cannot be stated explicitly through spoken language (McNeill, 1992). There are different views regarding the purposes for gesture use during interpersonal exchanges and learning activities (Rauscher, Krauss, & Chen, 1996; Kita, 2000; Emmory & Casey, 2001). The study views functions of children's gestures through the Information Packaging Hypothesis (Kita, 2000).

The Information Packaging Hypothesis suggests that speech and gestures are independent systems that become coordinated when focused on a common goal (Kita, 2000). According to Kita (2000), gestures combine spatio-motoric information into units that can be accessed and integrated by other systems to form concepts. The Information Packing Hypothesis suggests that the combination of speech and representational gestures show the unification language with mental representations to present a complete message (Alibali, et al., 2000). Studies observing children's use of gestures through the perspective of the Information Packaging Hypothesis indicate that there is an increase in gesturing when visuo-spatial and linguistic information is difficult to integrate and conceptualize (Hostetter et al., 2007). Given the visuo-spatial elements of

mathematics, the use of gestures to transition thoughts, the application of the Information Packaging Hypothesis may give insight in to the integration of information by children with FAS to learn a mathematical concept (Kita, 2000; Hostetter et al., 2007; Karmiloff-Smith, 1992).

- 2) Proficiency in mathematics requires the generation of accurate mental representations, the integration of conceptual and procedural knowledge, and the application of effective problem solving skills (Rittle-Johnson et al., 2001). Studies indicate that children use representational gestures as they learn new concepts in mathematics. Perry et al. (1998) found that children who presented different messages in spoken language as compared to their use of gestures when solving equivalence problems show transitions in learning. The researchers suggested that the children were integrating information and transitioning from an inaccurate and inconsistent state of understanding to a stable understanding (Perry et al., 1988). Alibali and Goldin-Meadow (1993) suggest that mismatches in speech and gestures signify the re-description of information and the transformation into a deeper understanding of the information and are ready to receive instruction (Karmiloff-Smith, 1992).
- 3) Children with developmental disabilities or genetic disorders such as Down syndrome, Williams syndrome, developmental coordination disorder, or with hemispheric brain lesions, do not exhibit a consistent pattern of gesture use (Laing et al., 2001; Mervis & Bertrand, 1997; Meanwell et al., 2006; Zoia et al., 2002; Caselli et al., 1998). Therefore, a distinct pattern of gesture use by children with developmental disabilities and FAS may not be identified. The effects from prenatal alcohol exposure impair visuo-spatial processing, the integration of verbal and visual information, and executive functions that impede learning (Ma et al., 2005; Uecker & Nadal, 1996; Kable & Coles, 2004a). It is not clear whether the cognitive impairments associated with the effects from prenatal alcohol exposure may influence the use of gestures by children with FAS to support communication and learning.
- 4) Based upon the theory of gesture functions presented in the Information Packaging Hypothesis and the impairments associated with the effects from prenatal alcohol exposure, it is possible that the deficits in cognitive processes that impede learning mathematics in children with FAS may be reflected in their use of gestures during the

learning process (Kita, 2000). Therefore, analyzing the gestures of children with FAS using the Information Packaging Hypothesis is to provide insight into their integration of visuo-spatial and linguistic information to assess how they construct their understanding of the concept of equivalence (Kita, 2000; Alibali et al., 2000).

- 5) Karmiloff-Smith (1992) formulated the Representational Redescription (RR) theory to counter developmental models that view learning as a linear trajectory. The RR model considers learning as cyclical overlapping transformation of thoughts (Karmiloff-Smith, 1992). The RR model suggests that thoughts are transformed from implicit retention to an explicit understanding through three recurring phases. In the first phase of the RR model, information is retained as isolated procedures separated from other forms of knowledge. In the second phase, the segmented procedures begin to be integrated with previous knowledge to form new concepts. However, some segmented pieces of information are maintained in the first phase of the process outlined in the RR model. The skills maintained at the first phase are rote or memorized facts needed for automatic recall. For example, the automatic recall of basic arithmetic facts allows for cognitive resources to be allocated to analyzing and interpreting the structure and goal of the problem needed to be solved rather than computation (Karmiloff-Smith, 1992; Alibali & Goldin-Meadow, 1993). During the third phase, knowledge is transformed to be generalized and accessed across cognitive process (Karmiloff-Smith, 1992).
- 6) Integrating the RR model with the coding of the observed gestures based upon the Information Packaging Hypothesis provides opportunities to identify changes in learning and possible difficulties with integrating information noted in children with FAS (Kita, 2000; Karmiloff-Smith, 1992; Kodituwakku, 2009).

The next chapter discusses the study design and the procedures used to investigate the influence of gestures used by children with an alcohol-related diagnosis while learning the concept of equivalence.

CHAPTER FOUR

DESIGN OF THE STUDY

4.1 INTRODUCTION

As discussed in the previous chapters, children who have a diagnosis of FAS may exhibit global cognitive delays and/or processing deficits that interfere with learning mathematics (Ma et al., 2005; Li, Coles, Lynch, & Hu, 2009; Matteson et al., 2006; Kopera-Frye et al., 1996; Burden et al., 2005; Howell et al., 2006). Studies have shown that children and youth affected by prenatal alcohol exposure exhibit weaknesses with estimating number numbers, extended response times to compute mental arithmetic problems, and exhibit low scores on mathematic achievement tests (Kopera-Frye et al., 1996; Burden et al., 2005; Howell et al., 2006).

The results from efficacy studies of the Math Interactive Learning Experience (MILE) a mathematics intervention for children with FAS indicate children with FAS made overall gains in mathematics when provided intervention (Kable et al., 2007; Howell, et al, 2006). While studies show that children with FAS respond to instructional interventions in mathematics, the studies focus on outcomes rather than how children with FAS learn mathematics.

Gestures are noted to serve multiple functions during the learning process. Research suggests that gesturing facilitates the integration of information to form new concepts, to organize visual-spatial information, and to express ideas that are difficult to verbalize (Kita, 2000; Hostetter et al., 2007; Melinger & Kita, 2007; Rittle-Johnson, Siegler, & Alibali, 2001). Children and adults use gestures to direct attention to the perceptual elements of a mathematics problem (Carlson, Avaarmides, Cary, Strasberg, 2007; Goldin-Meadow et al., 2009). Gestures are used to connect mental representations to a real world context to support problem solving (Carlson et al., 2007). For example, children may point and move their finger up in the air to represent counting up a mental number line while solving an addition problem (Carlson et al., 2007). Children's gestures provide information about their readiness to learn and their transformation of concepts and procedures during the learning process (Alibali & Goldin-Meadow, 1993; Perry et al., 1988).

Given the deficits associated with the effects from prenatal alcohol exposure, it is possible that children with FAS may have difficulties processing and organizing information conveyed through the co-occurrence of gesture and speech to facilitate mathematics learning (Cook et al., 2008; Carlson et al., 2007; Goldin-Meadow et al., 2009).

The purpose of this study is to examine whether children affected by prenatal alcohol exposure use gestures to support their understanding of the concept of equivalence. The information gathered from this study may contribute to the understanding of the deficits in mathematics and learning associated with FAS. Also, the information from the study may guide the development of effective mathematical interventions for children affected by prenatal alcohol exposure, a population that has had minimal consideration in the literature on educational interventions (Kable & Coles, 2004a; Kable et al., 2007; Bertrand, 2009).

Chapter four presents the study design, the procedures used to collect the data, and the selection of statistical methods to analyze the information.

4.2 STUDY DESIGN

As discussed in chapter three, typically developing children often use gestures to support learning. However, given minimal information regarding the use of gestures to support learning in children with an alcohol related diagnosis is available (Millians et al., 2007). This study is to examine if children with FAS use gestures to support learning. The information may give insight as to how children with FAS processes information while learning mathematics and contribute to the development of effective interventions. The research problem, questions and hypotheses addressed in this study are discussed in the following section. Also, this section presents the theoretical basis for the study design.

4.2.1 Statement of the problem

Given the deficits with encoding and integrating information as well as decreases in processing speed, it is possible that children with an alcohol-related diagnosis are inefficient in interpreting and using speech and gesture to learn the mathematical concept of equivalence (Santhanam et al., 2009; Ma et al., 2005). Though deficits in mathematics are associated with the effects from prenatal alcohol exposure, few studies have examined how children with FAS learn a rudimentary mathematical concept, like equivalence (Kopera-Frye et al., 1996; Coles et al., 2009; Bertrand, 2009).

Understanding the relational meaning of equivalence is necessary to solve complex mathematical problems (Seo & Ginsburg, 2003; McNeil & Alibali, 2004; McNeil & Alibali, 2005). The equals sign indicates that numbers on both sides of the sign are the same. Often young children interpret the equals sign as an operational symbol that refers to the answer of a problem (Seo & Ginsburg, 2003). When given direct instruction and experiences with a variety of mathematical problems, many children learn to interpret the equal sign to indicate an equivalent relationship among values (McNeil & Alibali, 2005).

However some children continue to interpret the equal sign to mean the answer to a problem as they progress into higher levels of mathematics (McNeil, et al., 2006). Children who interpret the equal sign as part of the operation show a limited understanding of equivalence that hinders the generalizing of the concept to solve complex problems (McNeil & Alibali, 2004; McNeil & Alibali, 2005; Seo & Ginsburg, 2003; Karmiloff-Smith, 1992).

This study implements a pre-test-intervention-post-test format to investigate learning of the mathematical concept of equivalence. The use of a pre-test and post-test is to compare if there are overall differences in learning about equivalence between children with FAS and children without a clinical diagnosis who are similar in age, cognitive functioning, and have had similar educational experiences. The study uses systematic observations of gesture use to examine how changes in learning may occur during the intervention phase.

The study is designed to address three aims as stated in chapter one and in the following section.

4.2.2 Aims of the study

The aims of the study are presented below. Chapter one provides the rationale supporting the aims of the study.

- Children with FAS exhibit deficits in mathematics but when provided interventions, children with FAS are found to make gains in their performance in mathematics (Kable et al., 2007; Coles et al., 2009; Bertrand, 2009). The few studies investigating the mathematical deficits associated with the effects from prenatal alcohol exposure have not defined how children with FAS construct their understanding of a mathematical concept or skill (Kable, et al., 2007). Therefore, first aim of this study is to examine how children with FAS form their understanding of a mathematical concept.
- As discussed in the previous chapters, children use gestures to facilitate concept formation and learning (Alibali & Goldin-Meadow, 1993; Kita, 2000). However, there is a paucity of research examining the influence of gestures by children with FAS (Millians et al., 2007). The second aim of the study is to investigate if gesture use by children with FAS influences their understanding of a mathematical concept.
- The third aim of the study is to contribute to the understanding of the cognitive processes in relation to the deficits in mathematics associated with the effects from prenatal alcohol exposure (Kable et al., 2007). The information gathered from study is to contribute the development of effective interventions for prevalent population that have significant learning problems but who have had minimal consideration in the educational and intervention research literature (Bertrand, 2009).

The questions and hypotheses guiding this study are presented in the following section.

4.2.3 Study questions and hypotheses

A primary question and two sub-questions with related hypotheses are investigated in this study. The questions and the hypotheses are stated below.

4.2.3.1 Primary study question and related hypothesis

- Will children with prenatal alcohol exposure demonstrate a poorer understanding of equivalence as compared to children without a clinical diagnosis? This question will be explored through the first hypothesis. (H₁) Children in the alcohol exposed group will have lower scores on the pre-test and the post-test than the non-exposed group.

4.2.3.2 Sub-questions and related hypotheses

- Do children affected by prenatal alcohol exposure use fewer conceptual gestures to explain their understanding of equivalence as compared to children not exposed prenatally to alcohol? The question will be examined by the second hypothesis. (H₂) Children in the alcohol exposed group will use fewer conceptual gestures as compared to the non-exposed group.
- Will there be a correlation between children with prenatal alcohol exposure and use of gestures to explain their understanding and their results on the mathematics post-test? This question will be considered through the third hypothesis. (H₃) Children who demonstrate fewer conceptual gestures will score lower on the mathematics post-test.

4.2.3.3 Exploratory questions

Additionally, two questions are considered to examine whether age and cognitive functioning influence the use of gestures and learning equivalence.

1. Are there relationships between age, IQ, and the use of conceptual, operational, and total number of gestures?

2. Are age, IQ, and the use of conceptual gestures associated and predict learning of equivalence?

4.2.4 Theoretical foundations of the study design

The study is to investigate the learning of mathematics in children with an alcohol related diagnosis by examining their coordinate use of gesture and speech. The study applies elements of a microgenetic approach within a quasi-experimental design to examine the learning processes and the outcomes in children with FAS as compared to a control group of children who do not have a history of medical complications and/or clinical diagnoses (Granott & Parziale, 2002; Shadish & Luellen, 2006).

Microgenetic studies, also referred to as microdevelopmental studies, examine the learning process rather than the differences in outcomes (Granott & Parziale, 2002). Microgenetic studies are characterized by three primary attributes (Siegler, 2006; Granott & Parziale, 2002; Chin, 2006). First, microgenetic studies cover changes in the learning process from the beginning until learning has stabilized (Granott & Parziale, 2002, p. 6). Second, the changes in learning are gathered by constant recording of observations that are “high relative to the rate of change” (Siegler, 2006, p. 469; Granott & Parziale, 2002). Third, the observations are analyzed and used to infer the processes that influence changes (Siegler, 2006; Granott & Parziale, 2002). Quantitative and qualitative methods are used to analyze the data gathered during the observations and enable investigators to distinguish the patterns and the interrelations among learning processes (Granott & Parziale, 2002). Microgenetic studies have been used to study changes in learning in diverse populations and in educational settings (Siegler, 2006). The microgenetic methodology is considered to provide the necessary framework to investigate the changes in learning exhibited by children affected by prenatal alcohol exposure.

Also, the study is based upon the research conducted by Alibali and Goldin-Meadow (1993) and by Perry et al. (1988). These studies utilized aspects of a microgenetic approach to investigate children’s co-occurrence of speech and gesture to identify transitions in learning the concepts of equivalence and conservation (Alibali & Goldin-Meadow, 2002; Chinn, 2006).

The study examines changes in learning through the systematic observation of the coordinated speech and gestures that occurred within a defined time period (Alibali & Goldin-Meadow,

2002). The analysis of the co-occurrence of speech and gesture is used to generate inferences about learning processes and knowledge stability in children with FAS in addition to providing information to generate recommendations to improve instruction. Therefore, the study fits within the definition of a microgenetic framework.

Similar to experimental studies, quasi-experimental studies test hypotheses by changing a factor in order to determine an outcome (Shadish & Lullen, 2006). Unlike experimental designs, quasi-experimental studies do not randomly assign participants to groups (Shadish & Luellen, 2006; Cook & Sinah, 2006). Given the assignment of the groups based upon the participants' diagnoses of FAS and pFAS or no clinical diagnosis, the study fits within a quasi-experimental framework (Shadish & Luellen, 2006). The study follows a pre-test-treatment-post-test experimental format (Gravetter & Wallnau, 2007; Shadish & Luellen, 2006).

Participants who solve less than 90% of the problems correctly on the pre-test move to the treatment phase of the study. The treatment phase requires the participants to watch an instructional video and to complete three practice problems. After completion of the learning activity, a post-test is administered. The learning outcomes are measured by the differences between the participants scores on the pre-test to the scores on the on the post-test. The raw scores on the post-test are compared with the speech and gesture units to determine if there is a relationship between the learning patterns and the performance on the post-test. Though learning outcomes are evaluated, the primary focus of the study is to assess how children with FAS function while learning mathematics in order to address learning difficulties or misunderstandings before failure (Shadish & Luellen, 2006). The purpose of the study's combined methods is to provide a comprehensive view of the learning processes and the stability of learning in children with FAS within the task demands.

The study's protocol to minimize risk of harm and to protect the participants' and their families' sensitive information is discussed in the next section.

4.2.5 Ethical Considerations

In the United States and in South Africa biomedical and behavioral studies with human participants are reviewed, monitored, and regulated by organizations to ensure that research is conducted in an ethical manner in accordance to each country's laws. In the United States, behavioral and biomedical studies are reviewed, monitored, and regulated by the Institutional Review Board.

This study investigates changes in learning in children with and without a medical diagnosis of FAS or pFAS. According to the regulations of the Institutional Review Board, this study falls under the category of behavioral research with participants who are considered to be a vulnerable population. Therefore, prior to beginning the research, the study's methods and protocols to minimize risk to the participants were reviewed and approved by the Institutional Review Board of Emory University. A review of the ethical standards is beyond the scope of this dissertation but may be found at the website of the Institutional Review Board of Emory University at www.irb.emory.edu.

The factors to protect the participants' confidential health information and to minimize risk of harm are discussed in the following section.

4.2.5.1 Protective factors

An overview of the study's protocol approved by the Institutional Review Board of Emory University used in this study to prevent the risk of harm and to maintain the confidentiality of the participants is discussed below. Copies of the recruitment letters, the consents, and assents, and the letter to revoke consent to participate in the study approved by the Institutional Review Board are provided in the Appendices A through F.

- 1) The study's procedures are considered non-invasive and to have minimal risk to the participants.

- 2) The participants' sensitive health information is kept strictly confidential as required under the Health Insurance Portability and Accountability Act (HIPPA). The participants' identifying information is de-identified for this study. Each participant is given a unique number that is to be used in place of a name or any other identifying information. The use of the identification number is to prevent possible connection of the participants with the study. Identifying information is stored separately in a locked cabinet from the research documentation. The video tapes of the participants are labeled with the identification numbers and stored separately in a locked cabinet from the identifying information. No pictures or video from the study are to be used in any publication or presentations in order protect the identities of the participants. The video tapes are to be destroyed upon completion of the study. Only the primary investigators, officials with the Institutional Review Board, and/or officials from governmental agencies as stated by law have access to the identifying and protected health information collected for this study.

- 3) Procedures are implemented to ensure that the children and their caregivers understand the risks and the requirements of the study. Each caregiver is asked to read, to discuss, and to sign consents that they understand the purpose, the procedures, and the possible risks of participating in the study before they are enrolled. The consents contain the contact information of the researchers and the Institutional Review Board of Emory University. The caregivers are instructed to contact the researchers immediately if they have any questions, concerns, or if they would like to withdraw from participating from the study. Each caregiver is provided with a form letter to revoke consent if they decide to withdraw from the study. The caregivers are informed that once the researchers receive the notice to withdraw from the study, no further data is gathered from their participation and their identifying and protected health information is destroyed.

- 4) Children in the study who are between the ages of eight and eleven discuss the expectations of the study with the researchers. The children sign verbal assents if they agree to participate in the study. Children who are twelve years of age or older discuss with the researchers the expectations of the study. The children are asked to sign a written consent form if they agree to participate in the study.

- 5) It is stated explicitly in the consents and the assent forms that participation in the study is voluntary. No repercussions such as loss of clinical services or punishments to the children are to occur if they decline participation.

The following section presents the methods, approved by the Institutional Review Board of Emory University, used to conduct the study.

4.3 METHODS

As stated in chapter one and earlier in this chapter, the study utilizes a quasi-experimental design within the theoretical framework of a microgenetic approach. The selection of the participants, eligibility to participate, and the study's procedures are discussed in the following sections.

4.3.1 Participants

A purposeful sample selection is used to conduct the study (Mertens & McLaughlin, 2004). The children participating in this study are to be between 8.0 and 12.9 years of age and reside within the metropolitan area of Atlanta, Georgia in the United States.

Eight of the children have a diagnosis of FAS or pFAS as determined by the Fetal Alcohol Syndrome Interdisciplinary Team at the Marcus Autism Center in Atlanta, Georgia and comprise the Alcohol Exposed group. The Fetal Alcohol Syndrome Interdisciplinary Team follows the criteria established by the IOM to confer the diagnosis of FAS or pFAS (Stratton et al., 1996). As discussed in chapter two, children who receive a diagnosis of FAS exhibit growth deficiencies below the national 10th percentile, alcohol related dysmorphia, and cognitive impairments. Children who have documented evidence of maternal alcohol use during pregnancy, and exhibit either growth deficiencies or cognitive impairments that are not explained by other medical causes or developmental disabilities may receive a diagnosis of pFAS (Bertrand et al., 2004).

Eight children comprise the Non-exposed group. The children in the Non-exposed group exhibit a typical developmental profile and do not have reported evidence of prenatal alcohol exposure. Also, the children in the control group do not have learning disabilities, clinical mental health or behavioral diagnoses or medical conditions that may interfere with learning.

Participants are recruited from the Marcus Center Prenatal Research and Development Project: An FAS Database. The Database provides abstracted information on individuals who have received a diagnosis of FAS. The children and their caregivers have signed consents to release their protected health information and contact information for the purpose of receiving updates about resources and opportunities about participating in research studies investigating the effects from prenatal alcohol exposure.

4.3.2 Eligibility

A comprehensive record review of the participants' medical and developmental history is conducted to determine eligibility. Participants are to be between eight and twelve years of age at the time of the study and have resided with their current caregivers for at least six months. Children need to be with a consistent caregiver in an attempt to limit changes in performance that may be related to changes in home life. The participants' overall cognitive ability is to fall within the Borderline to the Average range of functioning as shown by their performance on a standardized cognitive abilities test administered by a licensed clinical or school psychologist. Standard scores ranging between 70 and 79 are classified as in the Borderline range of function on standardized tests that measure intellectual functioning with a mean of 100 and a standard deviation of 15 points. Standard scores that range between 80 and 89 are classified as in the Low Average range and scores that range between 90 and 109 are classified as in the Average range (Sattler, 2001). This is to control for variations in performance that may be associated with extremely low or high cognitive abilities.

Participants are excluded from the study if they exhibit greater than a twenty point discrepancy between their overall intellectual functioning and their verbal or nonverbal reasoning scores. Educators debate the usefulness of a discrepancy among scores to identify a learning disability however inconsistencies among subtest scores may reflect an uneven pattern of development and cognitive impairments (Kavale & Forness, 2003; Fletcher, Morris, & Lyon, 2003; Sattler, 2001). Also, participants are excluded from the study if English is their second language. An increase of gesture use often occurs when learning a second language (Nicoladis, 2007). Limiting the participants to primary English speakers is to reduce a possible increase of gesture use to support learning a second language.

Participants are excluded from the study if they exhibit severe emotional and /or behavior disturbances as well as a history of chronic school absences. This is to limit changes in performance that may occur due to inconsistent instruction. Lastly, participants are excluded from participating in the study if they answered ninety percent or more of the problems on the pre-test correctly. Children who receive a pre-test score of ninety percent or better may not respond to instruction or use of gestures due to their stability of knowledge reflected in their mastery of the concept (Karmiloff-Smith, 1992; Alibali & Goldin-Meadow, 1993; Alibali & Goldin-Meadow, 2002).

4.3.3 Procedures

The study is conducted in two sessions. Each participant completes the sessions individually with the investigator. The first session requires the participant to complete a pre-test on equivalence and to watch the instructional video. The instructional video covers the concept of equivalence and the different strategies to solve equivalence problems using addition. After viewing the instructional video, each participant solves three equivalence problems similar to those taught on the video. The participant is asked to explain how the problem is solved. The participant is videotaped during the practice exercise for analysis.

The second session consists of completing the post-test. It occurs one week after each participant's completion of the first session. A discussion of the instructional video and the practice exercise occurs in later in this chapter.

4.3.4 Pre-test and post-test

The use of a paper and pencil test is to maintain the common practice of using written problems or worksheets to document learning outcomes. Table 1 provides the problem formats and categories used for the pre-test, the practice activity, and the post-test.

Table 1: Problem Formats and Categories for Equivalence Problems

Problem Formats	Problem Categories
$a+b+c=$ ___	Add All
$a+b+c=$ ___+c	Initial Blank Equivalence
$a+b+c=a+$ ___	Final Blank Equivalence

The pre-test and the post-test are to gather information about the participants initial understanding of equivalence and their understanding after participating in the learning activity. The scores from the pre-and-post test compared with the results from the gesture observations provide information from different measures to assess the changes the changes in learning (Alibali & Goldin-Meadow, 1993; Brainard, 1977).

The pre-test and the post-test each consist of a total of fifteen problems. These fifteen problems fit within one of three problem formats 1) Add All, 2) Initial Blank Equivalence, and 3) Final Blank Equivalence (Alibali & Goldin-Meadow, 1993; Alibali & Goldin-Meadow, 2002). The tests are based upon the problem formats used in the 1993 study conducted by Alibali and Goldin-Meadow. The tests are considered to be valid in content given the content measured and the use of the formats in a previous study (Crocker, 2006). The pre-test was labeled Worksheet #1 and the post-test was labeled Worksheet #2 when presented to the students. The post-test included three problems with multiplication that could be solved using the same strategies. The multiplication problems were not included in statistical analysis. The multiplication problems were used as an informal task to assess generalization. Appendices G and H provides examples of the pre-test and the post-test.

To determine the stability of the pre-test and the post-test, parallel forms reliability is conducted. The pre-test and the post-test were administered to thirty-seven children in third and fourth grades who attend a private school in Atlanta, Georgia prior to beginning the study. The post-test was administered to the same third and fourth graders one week after they completed the pre-test to simulate the study procedures. The children did not receive the intervention. The scores are analyzed using Cronbach's alpha (α) with an agreement of .80 indicating the measures are consistent. A discussion of the validity and the results from the reliability analysis is presented in chapter five.

4.3.5 Intervention

The intervention for the study consists of a mathematics instructional video and practice exercise. The intervention is designed to emulate a common classroom approach of providing whole group instruction and practice solving problems similar to those in the lesson (Hiebert et al., 1999).

4.3.5.1 Instructional video

After completing the pre-test, each participant watches a ten minute instructional video. The use of an instructional video is to ensure that all participants receive the same instruction on equivalence. A trained special education teacher conducts the video lesson on equivalence. The problems used in the instructional video follow the same format as the problems on the pre-test, the post-test, and the practice exercise.

The video presented to the participants discusses the concept of equivalence to mean the “same as” and the procedures to solve the mathematic problems (Seo & Ginsburg, 2003; Alibali & Goldin-Meadow, 1993). The concept of equivalence is taught in relation to procedures to solve each problem type in the instructional video (Ma, 1999; Donovan & Bransford, 2004). The instructor in the video demonstrates the procedures to solve each problem type, which is a common instructional approach used in schools in the United States (Hiebert et al., 1999; Ma, 1999).

The instructor uses conceptual gestures when discussing the concept of equivalence and operational gestures when explaining the steps to complete the problems. The use of gestures is to assist in connecting the verbal explanations to the visual formats of the problems (Goldin-Meadow, Kim, & Singer, 1999). The procedures to solve each problem type are presented individually. The instructor uses a consistent format to solve each problem. The instructor reads each problem out loud and demonstrates the techniques for planning the steps to solve the problems. While solving the problems, the instructor verbalizes the thinking processes and uses gestures to explain the solution. After solving the problems, the instructor reviews why the problem was equivalent and the procedures to solve the problem. This is to model systematic approaches to problem solving similar to those used in the MILE program, a mathematics intervention program for children with FAS (Kable et al., 2007; Bertrand, 2009).

The video presents one example as to how to solve an Add All problem. The participants are required to have a basic understanding of addition before participating in the study. Also, the video contains two examples as to how to solve an Initial Blank Equivalence problem and two examples as to how to solve a Final Blank Equivalence problem.

A description of the instructional procedures is presented in the following sections.

4.3.5.1.1 Instruction for add all problems

The instructor solves the problem by adding all of the digits on the on the left of the equation and writes the sum in the answer blank. Next, the instructor calculates the sum on the left side of the equals sign and writes the number under the left side of the equation. The instructor compares the numbers on the left and right sides and states they are the same. The instructor explains the solution is correct by showing that the sum on the left side of the equal sign is the same as or equivalent to the solution written in the answer blank.

4.3.5.1.2 Instruction for initial blank and final blank equivalence problems

The instructor adds the numbers on the left side of the equation and writes the sum below the left side of the equation. The instructor identifies, points to, and circles the digits that are the same on each side of the equals sign. The instructor adds the digits that are not circled on the left side of the equation and writes the sum in the answer blank. She explains the number circled on the left side of the equation is not included in the calculation because the same number is on the right side of the equation. The instructor checks the problem to see if each side of the equation shows the same amount. The instructor adds the digits on the left side of the equation and writes the sum below it. The instructor adds the numbers on the right side of the equation and writes the sum below it. The instructor compares the sums on each side of the equation to show that the amount on the left side is the same as or equivalent to the amount on the right side of the equal sign.

Immediately following the instructional video, the participants completed the practice exercise. The participants spent approximately forty-five minutes to view the instructional video and to complete the practice items. The length of time spent with the intervention was consistent with

the duration of mathematics instruction in many schools in the United States. Researchers with the committee on Trends in International Mathematics and Science Study (TIMMSS) in 1999 used video to investigate the similarities and differences of eighth grade mathematics classroom instruction in the United States, Germany, and Japan. According to the study, the average duration of an eighth grade mathematics class in the United States was forty-nine minutes with classes ranging between thirty-two minutes and ninety-one minutes (Hiebert et al., 1999).

4.3.5.2 Practice exercise

The practice exercise requires participants to solve three equivalence problems that follow the same formats found on the pre-test, the instructional video, and on the post-test. Table 2 presents the practice problems in the order they are presented. The problems are written on a white board at each participant's eye level and within reach. Each participant is to solve the same problems on the white board.

Table 2: Practice Exercise Problems and Categories

Problems	Problem Categories
$5+2+1= ___ +1$	Initial Blank Equivalence
$4+4+8= ___$	Add All
$2+4+6=2+ ___$	Final Blank Equivalence

After completing each problem, the participant explains how the problem is solved. The investigator is allowed to use three verbal prompts to direct each participant to elaborate on the response. The first verbal prompt is "how would you solve this problem?" The second verbal prompt is "how did you get the answer?" The third verbal prompt is "tell me more." The investigator is to refrain from using arm and hand movements as well as wording that may elicit gestures during the explanation task.

Each participant's explanation is videotaped. The camera is angled to record the participants' movements and their verbal responses as they solve the problems. The video is downloaded onto a laptop computer and transcribed using Transana 2.0 coding software (Fassnacht & Woods, 2005).

The following section discusses the transcription and the coding procedures used to analyze the participants use of speech and gestures during the learning process.

4.3.6 Coding of speech and gestures

The coding process occurs in three phases. First, the children's verbalizations are transcribed verbatim to identify key words that indicate their interpretation of the equals sign. Second, the children's gestures are be coded according to the starting point, the positioning, and the motion of the hands to indicate the type of information they are expressing. Third, the verbal transcriptions and the coded gestures are coordinated and categorized as either an operational speech and gesture unit or a conceptual speech and gesture unit (Kita, 2000; Alibali & Goldin-Meadow, 1993).

Operational speech and gesture units reflect the procedure used to solve the problem without signifying the relationship of numbers on each side of the equals sign. Table 3 provides the key words and the description of the gesture movements for operational gestures (Kieran, 1981; Alibali, & Goldin-Meadow, 1993; McNeil & Alibali, 2004; McNeil, et al., 2006).

Table 3: Key Words and Movements for Operational Gestures

Key Words	Gestures
Is	Point with flat hand or with finger at the blank or equals sign.
Makes	Staccato pointing at each number and stopping at the answer blank.
Answer	Stops the hand at the equals sign or answer blank.
Total	Continuous sweep under the problem stopping at the answer blank.
Sum	Points or stops at the end of the problem or at the answer blank.

Conceptual speech and gesture units reflect the understanding of equivalence (McNeil & Alibali, 2004; McNeil & Alibali, 2005). Table 4 provides the key words and gestures indicating understanding of the concept of equivalence.

Table 4: Key Words and Movements for Conceptual Gestures

Key Words	Gestures
The same as	Hands placed under or around both sides of the equation; hands held equidistant apart referring to each side of the problem.
Equal or equivalent	Using hands or a point, giving a smooth sweep under one side of the problem followed by a smooth sweep under the other side of the problem.
They (meaning both sides) are the same	Hands cupped around each side of the problem; C-shaped hands enclosing each side of the problem.

The speech and gesture unit matches are counted and categorized. A speech and gesture match is when the verbal information provides the same message about the operation or concept as gesture. Information presented through speech and gesture matches may indicate stability of the learning process (Breckinridge Church & Goldin-Meadow, 1986; Perry et al., 1988; Alibali & Goldin-Meadow, 1993).

Often children's speech and gestures do not convey the same information as they learn a new concept or skill. Mismatches in speech and gesture suggest that children have elements of the concept but have not integrated the information fully to be expressed through language or consistent application to solve problems (Alibali & Goldin-Meadow, 1993; Perry et al., 1988).

Studies suggested that children's speech and gesture mismatches may indicate an implicit understanding of information that has not become integrated fully to be expressed through language (Broaders et al., 2007; Perry et al., 1988; Kita, 2000). In cases where there are speech and gesture mismatches, the units are categorized according to the type of information present in gesture. The coding and categorization of the speech and gesture units are to be analyzed to determine the participants' level of understanding of the concept of equivalence and the application of the procedures to solve the addition equations.

A second investigator, unaware of the children's age, diagnoses, and group assignment is to code twenty-five percent of the tapes to determine the reliability of the coding method. An intraclass correlation is conducted to determine the inter-rater reliability. The gesture protocol is considered reliable if the intraclass correlation coefficient is .80 or greater (von Eye & Mun, 2005). A discussion of the validity of the gesture protocol and the results from the reliability analysis is presented in chapter five.

The statistical methods selected to analyze the results from the pre-test, post-test, and the gesture observations are discussed below.

4.4 STATISTICAL METHODS

Statistical measures are selected to investigate changes in learning between the groups and to investigate whether the use of gestures influence the changes. The selection of statistical procedures is discussed in relation to each hypothesis. SPSS version 17.0, statistical software is used to analyze the data.

4.4.1 Statistical analysis for hypothesis one

First, it is hypothesized that the children in the alcohol exposed group will have lower scores on the pre-and-post test than the non-exposed group. Independent samples *t* tests ($\alpha = .05$) are conducted to compare the difference mean scores of the pre-test and the post-test of the Alcohol Exposed group to the Non-Exposed group (Gravetter & Wallnau, 2007). Also, paired samples *t* tests ($\alpha = .05$) are conducted to compare the pre-test mean to the post-test mean to examine if there are changes in learning in each group.

4.4.2 Statistical analysis for hypothesis two

Second, it is hypothesized that children in the Alcohol Exposed group will use fewer conceptual gestures than the children in the Non-exposed group. The gesture data is organized into categories and does not fit within a normal distribution, a non-parametric, chi-square test of independence ($\alpha = .05$) is conducted. To investigate the effect size of the difference in gesture use between the two groups, an odds ratio is conducted.

4.4.3 Statistical analysis for hypothesis three

Third, it is hypothesized that children who use fewer conceptual gestures will exhibit lower scores on the post-test. Pearson correlations, two-tailed ($\alpha=.05$) are conducted to investigate the association between the use of conceptual gestures and the results on the post-test (Gravetter & Wallnau, 2007). Also, Pearson correlations are conducted to investigate if there is a relationship between operational gestures and conceptual gestures on the post-test and the pre-post test difference scores.

The Pearson correlation (r) is useful in describing the degree and the direction of the linear relationship between two variables (Gravetter & Wallnau, 2007). The relationships between the variables are categorized as being positive or negative correlations. The degree of the correlation indicates the consistency of relationships between the variables. A correlation of 1.00 or -1.00 indicates a perfect correlation between two variables (Gravetter & Wallnau, 2007).

A positive correlation suggests that the variables move in the same direction (Gravetter & Wallnau, 2007). For example the more use of gestures the higher the test scores. Also the inverse can be applied and indicates the fewer gestures used, the lower the test scores. A negative correlation suggests that the variables move in opposite directions. For example, the more use of gestures, the lower the test scores. Again, the inverse can be applied and indicates the fewer use of gestures, the higher the test scores.

4.4.4 Exploratory analysis

Two questions guide the exploratory analysis to investigate other factors that may affect learning. The questions are as follows: 1) Are there relationships between age, IQ, and the use of conceptual, operational, and the total number of gestures? 2) are conceptual gestures, age, and/or IQ, associated and predict learning of equivalence?

To investigate whether there are relationships between age, IQ, and the number of conceptual, operational, and overall use of gestures, Pearson (r) correlations ($\alpha=.05$) are conducted. Additionally, a multiple regression analysis ($\alpha=.05$) is conducted to investigate whether conceptual gestures, conceptual gestures and age, and/or conceptual gestures, age, and IQ predict learning equivalence.

A summary of the methods used to conduct the study is presented in the next section.

4.5 SUMMARY OF CHAPTER FOUR

A synopsis of the study's aims, design, and methods are presented below.

- 1) First, the study is to examine how children affected by prenatal alcohol exposure construct their understanding of the mathematical concept of equivalence. Second, the information gathered is to contribute to the understanding of the cognitive processes and learning challenges experienced by many children with FAS. Third, the findings from the study may provide information to assist in developing effective intervention to address the learning needs of children with FAS (Bertrand, 2009; Kodituwakku, 2009). The aims of the study are examined through the study questions, hypotheses, and the exploratory analysis.
- 2) The study uses a quasi-experimental design (Shadish & Luellen, 2006). The participants are assigned to groups according to their diagnosis. Eight children with a diagnosis of FAS or pFAS comprise the Alcohol Exposed group and eight children with no clinical diagnosis comprise the Non-exposed group (Shadish & Luellen, 2006). The children in the study are between the ages of eight and twelve and are matched by intellectual functioning, exposure to a similar quality of education, and must speak English as their primary language. The study controls are to limit outside factors that may influence the learning outcomes (Shadish & Luellen, 2006; Nicoladis, 2007).
- 3) The study uses mixed methods to investigate how children with FAS learn the concept of equivalence. The study is based upon a microgenetic framework that examines changes in a narrowly, defined behavior or skill from the initiation of the learning process until mastery (Siegler, 2006; Chinn, 2006). The purpose for using a microgenetic framework is to examine the transitions in the learning process rather than focusing on overall outcomes (Siegler, 2006). Systematic observations of the children's gestures are to gather information as to how children change their thought processes the administration of a pre-test and post-test is to identify if there are overall changes in learning.
- 4) Validity and reliability analyses of the pre-test and the post-test as well as for the gesture protocol are conducted. Parallel forms reliability is conducted. The pre-test and the post-test are administered to thirty-seven children who attend a private school in Atlanta, Georgia before conducting the study. The pre-test and the post-test are considered reliable if there is an agreement above .80 between the forms using Cronbach's alpha.

Inter-rater reliability is conducted to examine the validity and the consistency of the gesture coding protocol. A second investigator who is unaware of the participants' group

assignments and diagnoses is to code twenty-five percent of the tapes. An intraclass correlation with an agreement co-efficient of .80 or above suggesting that the gesture protocol is valid and reliable is to be conducted.

- 5) Inferential statistics are used to analyze the data from the study. The hypotheses and the selected statistics are as follows;
- a. Hypothesis 1 proposes that children with FAS will have lower scores on the pre-test and on the post-test as compared to the children in the Non-exposed group. Independent samples *t* tests ($\alpha=.05$) are used to compare the test scores.
 - b. Hypothesis 2 proposes that the children with FAS will use fewer conceptual gestures while learning the concept of equivalence than the children in the Non-exposed group. A chi-square test of independence ($\alpha=.05$) and an odds ratio are used to examine if there are differences in gesture use between the two groups and the effect size.
 - c. Hypothesis 3 proposes that children who use fewer gestures will exhibit lower score on the post-test. Two-tailed, Pearson correlations ($\alpha=.05$) are used to examine if there is an association between the use of conceptual gestures and the result on the pos-test.
 - d. The exploratory analysis examines other factors that may affect learning. Multiple regression analysis is used to examine whether there are relationship between age, IQ, the number of procedural, conceptual, and/or the overall number of gestures used and the learning of the concept of equivalence.

The results from the study are presented in chapter five.

CHAPTER FIVE

DATA ANALYSIS AND INTERPRETATION

5.1 INTRODUCTION

This exploratory study uses a quasi-experimental design to investigate how children with a diagnosis of FAS or pFAS learn the mathematical concept of equivalence as compared to children without a clinical diagnosis.

As discussed in chapter four, the study fits within a quasi-experimental design due to group assignments based upon a diagnosis of FAS, pFAS, or no clinical diagnosis. The study follows a pre-test-treatment-post-test protocol (Shadish & Luellen, 2006). The administration of a pre-test and a post-test is to investigate whether there is a change in the children's overall learning of equivalence after viewing the instructional video and completing the practice exercise.

The study is approached through a microgenetic perspective to investigate if gesturing is associated with learning the mathematical concept of equivalence (Goldin-Meadow & Alibali, 2002). Systematic observations of the participants' use of gestures as they practice solving equivalence problems are conducted (Chinn, 2006; Goldin-Meadow & Alibali, 2002). The gestures are coded and categorized according to the type of information expressed while solving the equivalence problems (Alibali & Goldin-Meadow, 1993; Perry, Breckinridge Church, & Goldin-Meadow, 1988). The data from the coding of gestures and the outcomes from the pre-test and the post-tests are analyzed to measure changes in learning (Seigler, 2006; Granott & Parziale, 2002). Inferential statistics are used to analyze the data in order to generalize the findings (Gravetter & Wallnau, 2007).

Chapter five presents a description of the participants of the study and the results from the statistical analysis.

5.2 SAMPLE

A description of the study's participants is provided in this section.

5.2.1 Participants

Information regarding the participants' cognitive functioning, medical and social history, and educational placement is gathered from a comprehensive review of records and interviews with the children's caregivers. The information is considered to be accurate. Table 5 presents the number of participants, the age, the cognitive functioning, and the educational placement of the participants in each group.

Table 5: Description of the Groups

	Alcohol Exposed	Non-exposed
Number	8	8
Age range in years	8.0-12.0	9.3-13.0
Mean age in years	9.2	10.7
Mean IQ ¹	86.875	90.000
Grade level range	2 nd -6 th	2 nd -7 th
Number retained in a grade ²	2	0
Number receiving special education	6	1

Twenty children are recruited to participate in the study. Four of the children are excluded from the study due to their scores of 100% on the pre-test. Scores above 90% suggest mastery of the

¹ Standard scores from a measure of intellectual functioning are unavailable for three of the children in the Non-exposed group. However, the records indicate their intellectual functioning to be in the Average range (SS=90-109).

² Information about retention is unavailable for one child in the alcohol exposed group and one child in the non-exposed group.

concept of equivalence (Alibali & Goldin-Meadow, 1993; Perry, Breckinridge Church, Goldin-Meadow, 1988).

Sixteen children are participating in the study. All of the participants reside within the metropolitan area of Atlanta, Georgia in the United States. The children's ages range from 8.0 years to 13.0 years. The mean age of the participants is 10.01 years. The study is designed to assess children ages 8.0 through 12.9 years, however, one child turned thirteen before the administration of the post-test. Eight children who have a diagnosis of pFAS or FAS comprise the Alcohol Exposed group. Eight children without a clinical behavioral, mental health or learning disorder as well as without medical conditions that would affect learning comprise the Non-exposed group. None of the participants are diagnosed with a sensory impairment. All of the participants speak English as their primary language.

Nine of the participants are female and seven are male. The families' income falls within the median income of 37,231 United States Dollars per year for Atlanta, Georgia (DeNavas, Proctor, & Smith, 2010, p.3). Eleven of the children are African-American and five are Caucasian. There are no participants of Hispanic, Native American, or Asian descent. The total group is 68% African-American and 32% Caucasian. According to the United States 2000 Census, the racial demographics of Atlanta, Georgia is approximated to be 61.4% African-American, 33.2% Caucasian, 4.5% Hispanic/Latino, 1.9% Asian, 0.2% of Native American or Alaskan, and an undetermined percentage of individuals of Pacific Island descent (Retrieved 29 January 2011 from <http://quickfacts.census.gov>). Based upon the 2000 Census, the sample selection for this study is reflective of the racial make-up of the population of the Atlanta metropolitan area.

The children's cognitive functioning falls within the Borderline to Average range on standardized intellectual measures with a mean of 100 and a standard deviation (SD) of 15 points. IQ scores that fall between 70 and 79 are classified as being in the Borderline range, scores that fall between 80 and 89 are classified as being in the Low Average range, and scores that fall between 90 and 109 are classified as being within the Average range of functioning (Sattler, 2001). The participants' standard scores (SS) range from 76 through 101 with a mean of 88.076. The intellectual functioning of three of the participants in the Non-exposed group are described as being within the Average range but standard scores are not reported in their records. Their scores are not included in the calculation of the mean of the participants' intellectual functioning.

All of the children have resided with their current caregivers for more than one year and are enrolled in school. Fourteen of the children attend public school. Two of the children attend private school. The children participating in the study are in either elementary or middle school. Six of the children in the Alcohol Exposed group receive special education services. One child in the Non-exposed group receives special education services. Two of the children in the Alcohol Exposed group have repeated a grade in school. None of the children in the Non-exposed group are reported to have repeated a grade. Information about grade retention is unavailable for two children. The public and the private schools the children attend are accredited by the Southern Association of Colleges and Schools. All but one of the public schools is considered to have met Adequately Yearly Progress as measured by the number of students in each school meeting grade level expectations on tests approved by the Georgia State Department of Education (Retrieved 29 January 2011, www.doe.k12.ga.us). Based upon a review of their educational placement, the children are considered to have received similar exposure to quality of curricula and instruction.

As stated in chapter four, the participation criteria are to limit factors that may affect the use of gestures while learning equivalence (Nicoladis, 2007; Alibali & Goldin-Meadow, 1993; Perry et al.1988). The groups are considered matched evenly by IQ, socio-economic status, and exposure to a similar quality of education.

The next section presents a discussion of the measures used to collect the data in this study.

5.3 MEASUREMENTS

A pretest, a post-test, and a gesture coding protocol are used in this study to collect information as to how children with FAS learn equivalence. The validity and the reliability of the measures are presented in this section.

5.3.1 Validity and reliability of the pre-test and post-test

The pre-test and post-test are based upon measures used in previous studies investigating gestures and learning to solve equivalence problems using addition (Alibali & Goldin-Meadow, 1993; Alibali & Goldin-Meadow, 2002; Perry et al., 1988; Crocker, 2006). The use of a pre-test is to acquire a baseline of children's understanding of solving equivalence problems using addition prior to the intervention. The post-test is to assess children's understanding of equivalence after the intervention. Both measures use the same problem formats shown in the instructional video. Given that the intervention and the tests assess the same concepts and procedures and are based upon prior studies, the measures are considered to be valid in content (Crocker, 2006).

To determine the stability of the pre-test and the post-test prior to conducting the study, thirty-seven children in third and fourth grades at a private school in Atlanta, Georgia were given the pre-test with the administration of the post-test one week later. The children did not receive the intervention after taking the pre-test. The mean of the children's pre-test and post-test were analyzed using Cronbach's alpha (α) to establish reliability with a co-efficient of .80 or above to indicate agreement between the measures.

Thirty-seven children were administered the pretest prior to conducting the study to establish reliability. The scores from the pre-test administered to the thirty-seven children had a mean of 13.162 with a standard deviation of 3.050 points. One week later, the post-test was administered to the same thirty-seven children. The scores from the post-test administered to the thirty-seven children had a mean score of 13.405 with a standard deviation of 2.862. The comparison of the pre-test scores to the post-test scores using the Cronbach's alpha suggests that tests are reliable $\alpha=.968$. The pre-test and post-test interclass correlation coefficient of average measures is .968 with coefficients in the 95% confidence interval ranging between .938 and .984. A one-way analysis of variance ($\alpha=.05$) shows no difference in the scores between the items within the group $F(1, 36) = 2.031, p=.163$. The findings indicate that the pre-test and the post-test are reliable and measure the same information. Therefore, the pre-test and the post-test can be used interchangeably to assess the overall changes in learning of equivalence for this study.

5.3.2 Validity and reliability of the gesture coding protocol

As discussed in chapter four, the gesture coding protocol is designed upon the methods use in other studies examining children's gesturing while learning (Alibali & Goldin-Meadow, 1993; Perry et al., 1988). A second rater, unaware of the children's age, intellectual functioning, school placement, and diagnoses, transcribed and coded the tapes of four of the participants, or 25% of the tapes. A review of the transcriptions suggests descriptive and interpretive validity as both raters identified that the children used similar language and gestures to explain their understanding of equivalence (Eisenhart, 2006). Reliability of the coding protocol is determined using the intraclass correlation coefficient. A coefficient of .80 or above is required to establish consistency of the coding method.

The mean of the gesture count for rater one is 7.625 (SD=6.390) and the mean of the gesture count for rater two is 7.250 (SD=6.065). The item mean is 7.439 with a variance of .070. The intraclass correlation coefficient average measure is .998 with coefficients in the 95% confidence interval ranging between .991 and 1.000. The results show consistency in the gesture coding between the two raters.

Summary

The pre-test and post-test are considered to be valid in content given they reflect the concept and the problem solving procedures taught in the instructional video (Alibali & Goldin-Meadow, 1993; Crocker, 2006). The gesture protocol is considered to be valid given the similarities between the two raters on their transcripts and coding. Also, the pre-test, the post-test, and the gesture coding protocol are based upon those used in previous studies (Alibali & Goldin-Meadow, 1993; Perry et al., 1988). The results indicate that the pre-and-post-test and the gesture protocol are reliable.

The next section discusses the results from the statistical analysis.

5.4 RESULTS OF STATISTICAL ANALYSIS

A primary question and two sub-questions are considered to investigate the use of gestures during the learning process in children affected by prenatal alcohol exposure. The following sections present the results of the reliability analysis of the measurements and the analyses of the data gathered in the study.

5.4.1 Primary research question and hypothesis one

Will children with prenatal alcohol exposure demonstrate a poorer understanding of equivalence as compared to children without a clinical diagnosis? The question is examined through hypothesis one that states children in the Alcohol Exposed group will have lower scores on the pre-test and the post-test than the Non-exposed group. Table 6 provides the mean, the standard deviation, and the standard error mean for the pre-test and the post-test scores for each group.

Table 6: Descriptive Statistics of the Pre-and-post-test for the Alcohol Exposed Group (N=8) and the Non-exposed Group (N=8), Total Participants (N=16)

Test	Mean	Standard Deviation	Standard Error Mean
<i>Alcohol Exposed</i>			
Pre-test	4.125	1.457	.515
Post-test	3.750	2.375	.839
<i>Non-exposed</i>			
Pre-test	4.625	.517	.182
Post-test	9.500	4.440	1.569
<i>Total Participants</i>			
Pre-test	4.375	1.087	.271
Post-test	6.625	1.136	4.554

Independent samples *t* tests ($\alpha=.05$) are selected to determine if there are significant differences in the mean differences of the pre-test and the post-test scores of the two groups. In

cases where the variance between the two groups is assumed to be unequal according to the Levene's test of variance of equality, adjustments are made to the degrees of freedom and to the range of scores within the 95% confidence interval. The changes indicated by the Levene's test of variance of equality are noted in the reporting of the results from the independent samples t test.

Pre-test

The purpose of comparing the pre-test mean scores is to examine whether the children in Alcohol Exposed group demonstrated a poorer understanding of equivalence prior to the intervention that consisted of watching the instructional video and completing the practice exercise as compared to the children in the Non-exposed group.

The mean difference between the groups is -.500, a standard error difference (SED) of .546 with the scores in 95% confidence interval ranging between -1.673 and .673. The results show no difference between the pre-test scores of the Alcohol Exposed group as compared to the Non-exposed group $t(14) = -.914, p = .376$, two-tailed. This indicates that the groups demonstrated a similar understanding of equivalence prior to viewing the instructional video and solving the problems during the practice exercise.

Post-test

A post-test is administered to each participant one week after completing the intervention to assess the overall learning of equivalence. To determine if there is a difference in the overall learning of equivalence between the two groups, an independent samples t test ($\alpha = .05$) is conducted to compare the differences of the means of the post-tests between the two groups.

The Levene's test of variance of equality indicated that equal variances between the groups are not assumed $F = 13.590, p = .002$. The difference of the mean of the post-test scores between the two groups is -5.755 (SED=1.780) with the scores in the 95% confidence interval ranging between -9.681 and -1.818.

The results indicate a significant difference between the post-test difference of the means of the Alcohol Exposed group as compared to the Non-exposed group $t(10.704) = -3.230, p = .008$, two-

tailed. This suggests that the children in the Alcohol Exposed group show no change in their learning of equivalence as compared to the Non-exposed group.

Pre-test and post-test comparisons by group

Paired samples t tests ($\alpha=.05$) are conducted to investigate if there are changes between the pre-test and the post-test scores for each group. The mean of the paired differences for the Alcohol Exposed group is .375 ($SD=1.933$, $SEM=.679$) with scores in the 95% confidence interval ranging between -1.232 and 1.982. There is no significant difference between the mean of the pre-test and the mean of the post-test of the Alcohol Exposed group $t(7) = .552$, $p=.598$, two-tailed. This suggests that the children in the Alcohol Exposed group showed no changes in their learning.

The mean of the paired differences for the Non-exposed group is -4.875 ($SD=4.051$, $SEM=1.432$) with scores in the 95% confidence interval ranging between -8.261 and -1.488. The difference between the pre-test and the post-test is significant for the Non-exposed group $t(7) = -3.404$, $p=.01$, two-tailed. This indicates that the children in the Non-exposed group demonstrated changes in their learning.

Summary

The results partially support hypothesis one. Hypothesis one states that children in the Alcohol Exposed group would have lower scores on the pre-test and on the post-test. There was no statistical difference in the means of the pre-test between the Alcohol Exposed and the Non-exposed groups. This suggested that the participants in the each group began the activity with similar understanding of equivalence. Specifically, the children in each group demonstrated the skills to compute the Add All problems accurately. Based upon previous studies, the children in the Alcohol Exposed group were expected to show poorer performance in their basic computation (Howell et al., 2006). Therefore, the similarities of the pre-test scores of the two groups is not predicted in hypothesis one.

There is a significant difference between the post-test scores of the Alcohol Exposed group as compared to the Non-exposed group. The Alcohol Exposed group exhibits lower scores on the post-test as compared to the Non-exposed group.

Also, the pre-test scores are compared to the post-test scores for each group. The findings show no difference in the pre-test and the post-test scores of the Alcohol Exposed group. There is a significant difference between the pre-test and post-test scores of the Non-exposed group. The results suggest that the children in the Alcohol Exposed group show no changes in the learning unlike the children in the Non-exposed group.

The second study question and hypothesis are discussed in the next section.

5.4.2 Second study question and hypothesis two

Do children affected by prenatal alcohol exposure use fewer conceptual gestures to explain their understanding of equivalence as compared to children not exposed prenatally to alcohol? This question is examined through hypothesis two that states children in the Alcohol Exposed group will exhibit a lower number of conceptual gestures as compared to the children in the Non-exposed group.

The descriptive statistics including the mean and the standard deviation for conceptual and operational gestures for the Alcohol Exposed group, the Non-exposed group, and for the total number of participants is presented in Table 7

Table 7: Descriptive Statistics of Operational and Conceptual Gestures for Alcohol Exposed (N=8), Non-exposed (N=8), and Total Participants (N=16)

Group	Gestures		
	Count	Mean	Standard Deviation
<i>Alcohol Exposed</i>			
Conceptual	2	.250	.707
Operational	219	27.375	27.463
<i>Non-exposed</i>			
Conceptual	16	2.000	3.162
Operational	151	18.875	9.963
<i>Total Participants</i>			
Conceptual	18	1.125	2.390
Operational	370	23.125	20.434

The number of gestures used by each participant in the Alcohol Exposed group and in the Non-exposed group was converted into a percentage to describe the frequencies of the procedural and conceptual gestures of the participants each group. In the Alcohol Exposed group, 12.5% of the children used 4 procedural gestures; 12.5 % used 6 procedural gestures; 12.5% used 11 procedural gestures; 12.5% used 16 procedural gestures; 12.5% used 26 procedural gestures; 12.5% used 32 procedural gestures; 12.5 % used 35 procedural gestures; and 12.5% used 89 procedural gestures respectively to explain their understanding of equivalence.

In the Non-exposed group, 12.5% of the children used 5 procedural gestures; 12.5% used 11 procedural gestures; 12.5% used 14 procedural gestures; 12.5% used 15 procedural gestures; 12.5% use 17 procedural gestures; 12.5% used 24 procedural gestures; 12.5% used 32 procedural gestures; and 12.5% used 33 procedural gestures respectively.

In the Alcohol Exposed group 87.5% of the participants did not exhibit the use of conceptual gestures. Yet, 12.5% of the children in the Alcohol Exposed group used 2 conceptual gestures.

In the Non-exposed group, 50.0% of the children did not use concept gestures while explaining the mathematical task. The results show that 12.5% of the children in the Non-Exposed group used 1 conceptual gesture; 12.5% used 2 conceptual gestures; 12.5% used 4 conceptual gestures; and 12.5% used 9 conceptual gestures respectively.

The distribution of the gesture frequencies used by the children in the Alcohol Exposed group and the Non-exposed group violate a normal distribution. Therefore, the non-parametric, chi-square test of independence ($\alpha=.05$) is used to analyze if there are differences in the types of gestures used between the two groups. Table 8 provides the observed and expected frequencies analyzed in the chi-square.

Table 8: Observed and Expected Frequencies of Conceptual and Operational Gestures for Alcohol Exposed (N=8) and Non-exposed (N=8) groups

Group	Gestures			
	Conceptual		Operational	
	Observed	Expected	Observed	Expected
<i>Alcohol Exposed</i>	2	10.25	219	210.75
<i>Non-Exposed</i>	16	7.75	151	159.25

The results indicate a significant difference in the use of the types of gestures between the Alcohol Exposed and the Non-exposed group $X^2(3) = 14.28$, $p=.000158$. Specifically, the children in the Alcohol Exposed group used significantly fewer conceptual gestures as compared to the Non-exposed group.

To assess the effect size of the difference in gesturing between the two groups, an odds ratio is conducted. An odds ratio measures the probability of the difference in the use of gestures to the probability of no difference in the use of gestures between the Alcohol Exposed and the Non-exposed group. A ratio of 1 indicates no relationship or effect. The odds ratio is 11.6026 with the

ratios in the 95% confidence interval falling between 2.6292 and 51.2021. This suggests that the children in the Alcohol Exposed group are 11 times more likely to show a difference in the use gestures, including conceptual gestures, than the children in the Non-exposed group

Summary

The results support hypothesis two. The findings indicate that the children in the Alcohol Exposed are observed to show difference in their use of conceptual gestures as compared to the children in the Non-exposed group.

The third study question and hypothesis are discussed in the next section.

5.4.3 Third study question and hypothesis three

Will there be a correlation between the types of gestures used and the outcomes on the mathematics post-test? The study question is investigated through the third hypothesis stating children who demonstrate fewer conceptual gestures will score lower on the mathematics post-test.

To investigate if there is an association between the use of conceptual gestures and the results on the post-test and the pre-post test difference score for the total group, Pearson correlations ($\alpha=.05$) are conducted. In addition, correlations are conducted to examine if there is a relationship between the use of between operational gestures and the post-test and the pre-post test difference scores.

To calculate the pre-post test difference scores, the raw scores of the pre-test are subtracted from the raw scores of the post-test to create the pre-post difference raw score for each participant in each group. The pre-post test differences are combined and transformed into mean scores for each group for further analyses. The mean of the pre-post test difference for the Alcohol Exposed group is $-.375$ ($SD=1.922$, $SEM=.679$). The mean of the pre-post test difference for the Non-exposed group is 4.875 ($SD=4.051$, $SEM=1.432$). Table 6 presents the descriptive statistics of the gesture types used by each group. A summary of the Pearson correlations is presented in Table 9.

Table 9: Summary of the Correlations for Gestures, Post-test and Pre-Post Test Difference for Alcohol Exposed (N=8), Non-exposed (N=8), and Total Participants (N=16)

Group	Post-Test	Pre-Post Difference
<i>Alcohol Exposed</i>		
Conceptual	-.468	-.762*
Operational	.595	.449
<i>Non-exposed</i>		
Conceptual	.458	.446
Operational	-.260	-.301
<i>Total Participants</i>		
Conceptual	.489 ⁺	.474
Operational	-.003	-.078

* $p < .05$, two-tailed; ⁺ $p = .054$, two-tailed

Conceptual gestures for total participants

The results indicate a trend toward a positive correlation between mean of the conceptual gestures and the post-test mean for the entire samples. A positive correlation suggests that for the total number of participants, those who used fewer conceptual gestures scored lower on the post-test. Also, a positive correlation suggests that for the total number of participants, those who use more conceptual gestures scored higher on the post-test.

Conceptual gestures by alcohol exposed and by non-exposed groups

The use of conceptual gestures is investigated for each group. The results showed a negative correlation between the mean of the conceptual gestures and the mean of the pre-post-test difference for the Alcohol Exposed group. This indicates that the children in the Alcohol exposed group who used more conceptual gestures exhibited a lower change between their pre- and post-test scores.

No significant correlation is found between the mean of the conceptual gestures and the mean of the post-test for both groups.

Operational gestures for total participants and by alcohol exposed and non-exposed groups

The results indicate no significant correlations between the mean of the operational gestures, the mean of the post-tests, as well as the mean of the pre-post difference for the Alcohol Exposed group, the Non-exposed group, and for the total sample.

Summary

The results support hypothesis three that states that children who use fewer conceptual gestures will score lower on the mathematics post-test for the entire sample.

The findings indicate a negative correlation between the use of conceptual gestures and the pre-post test difference score for the children in the Alcohol Exposed group. The results suggest that the use of conceptual gestures influenced learning of equivalence differently in the children in the Alcohol Exposed group as compared to the total sample.

Due to the findings, an exploratory analysis is conducted to examine whether age and IQ are related to the outcomes on the post-test and what factors predicted learning of equivalence.

5.4.4 Exploratory analysis

The participants' ages are between 8.0 years and 13.0 years. Because of the participants' age span and the differences in the learning between the Alcohol Exposed group and the Non-exposed group, two exploratory questions are examined to provide additional information on factors that may contribute to learning. The questions are stated below.

1. Are there relationships between age, IQ, and the use of conceptual, operational, and total number of gestures?
2. Are age, IQ, and the use of conceptual gestures associated and predictive of children's learning the concept of equivalence?

5.4.4.1 Exploratory question one

To explore whether there are relationships between age, IQ, and types of gestures used, Pearson correlations ($\alpha=.05$) are conducted. Table 4 summarizes age and IQ for the Alcohol Exposed and the Non-exposed groups. Tables 5 and 6 present the means, the standard deviations, and the standard error means for the pre-test, the post-test, and gestures. The summary of the correlations are provided in Table 10.

Table 10: Summary of the Correlations for Age, IQ, and Gesture Types for Alcohol Exposed (N=8), Non-Exposed (N=8), and Total Participants (N=16)

Group	Operational	Conceptual	Total
<i>Alcohol Exposed</i>			
Age	.892*	-.221	.890*
IQ	-.160	.487	-.148
<i>Non-exposed</i>			
Age	.105	-.223	.029
IQ ⁺	.024	.241	.087
<i>Total Participants</i>			
Age	.371	.018	.370
IQ ⁺	-.149	.314	-.113

⁺Standardized IQ scores for three of the participants in the Non-exposed group are not available and not included in the calculation, Non-exposed group (N=5), Total Participants (N=13), * $p<.01$, two-tailed

The results show a significant positive correlation between age, the use of operational gestures, and the total number of gestures in the Alcohol Exposed group.

The correlations between age and conceptual gestures are not significant for the total sample as well as for the Alcohol Exposed and Non-exposed groups. No correlations are shown between IQ and operational, conceptual, and total gestures.

Summary

The findings indicate that age is associated with operational gestures and the total number of gestures used by children in the Alcohol Exposed group. There is no association between IQ and gesturing.

5.4.4.2 Exploratory question two

To investigate if age, IQ, and conceptual gestures are associated with learning of equivalence, Pearson correlations and regression analysis ($\alpha=.05$) are conducted. Thirteen cases are considered in the analysis considering age, IQ, and the use of conceptual gestures to predict the learning of equivalence. The study included sixteen participants however standardized IQ scores are unavailable for three of the participants.

Table 11 presents the descriptive statistics and correlations for age, IQ, and conceptual gestures and the post test.

Table 11: Descriptive Statistics and Correlations for Post-test Dependent Variable and the Predictor Variables of Conceptual Gestures, Age, and IQ (N=13)

	Mean	Standard Deviation	Pearson Correlation			
			Post-test	Conceptual Gestures	Age	IQ
<i>Dependent Variable</i>						
Post-test	6.153	4.412	1.000	.405	.638*	.428
<i>Predictor Variables</i>						
Conceptual Gestures	1.000	2.516	.405	1.000	-.109	.314
Age	9.576	1.457	.638*	-.109	1.000	.169
IQ	88.076	6.969	.428	.314	.169	1.000

* $p<.01$, one-tailed

The findings suggest no correlation between age and IQ. Also, there is no correlation between IQ and the performance on the post-test for the entire sample. The results indicate a positive correlation between age and the outcomes on the post-test.

To investigate whether the factors of conceptual gestures, age, and/or IQ predict learning the concept of equivalence, a regression analysis is conducted. Table 13 provides the summary of the regression analysis for the variables predicting learning about equivalence.

Table 13: Summary of the Multiple Regression Analysis for Conceptual Gestures, Age, and IQ Predicting Post-test Outcome (N=13)

Variable	Model 1			Model 2			Model 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Conceptual gestures	.711	.483	.405	.843	.333	.481*	.733	.362	.418
Age				2.091	.582	.691**	1.975	.602	.652**
IQ						.	.118	.132	.186.
<i>R</i>		.405			.797			.816	
<i>R</i> ²		.164			.635			.655	
<i>Adjusted R</i> ²		.088			.562			.554	
<i>F</i> for change in <i>R</i>		2.161			12.923**			.802	

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

The variables of age and conceptual gestures predict the learning of equivalence. IQ is not found to predict the learning of equivalence. Also, conceptual gestures are not found to predict the learning outcomes on the post-test when separated from age and when included with age and IQ.

Summary

The findings indicate that age and conceptual gestures are not related but both contribute to the overall learning of equivalence.

A brief overview of the results of the data analysis is presented in the next section.

5.5 CONCLUSION

A synopsis of the data interpretation in relation to the study's hypotheses and exploratory questions is presented below.

1. The results suggest that hypothesis one is partially supported. Hypothesis one states that children in the Alcohol Exposed group will demonstrate a poorer understanding of equivalence as compared to the children in the Non-exposed group. Children in both groups exhibit similar scores on the pre-test. This is not predicted in hypothesis one. The comparison of the post-test means indicate that the children in the Alcohol Exposed group made no gains in their learning of equivalence after watching the instructional video and completing the practice exercise as compared to the children in the Non-exposed group.
2. The findings support hypothesis two. Hypothesis two states that the children in the Alcohol exposed group will exhibit a lower number of conceptual gestures as compared to the children in the Non-exposed group. The results indicate a significant difference in gesture use between the two groups with the children in the Alcohol Exposed group using fewer conceptual gestures.
3. The results support hypothesis three. Hypothesis three states that the children who use fewer conceptual gestures will score lower on the equivalence post-test. Overall, the children who use conceptual gestures received higher scores on the post-test. But, the children in the Alcohol Exposed group who use more conceptual gestures exhibited a lower difference between the scores on the pre-test and the post-test. The inverse can be applied and suggests that children in the Alcohol Exposed group who use fewer

conceptual gestures show a larger difference between the scores on the pre-test and the post-test. This suggests that the use of conceptual gestures to support the learning of equivalence differs between the two groups.

4. Because of the age range of the participants, an exploratory analysis is conducted to investigate whether age and/or IQ is associated with the use of conceptual and/or operational gestures and the outcomes on the post-test.
 - a. The analyses indicate that there is a relationship between age and use of operational gestures and total gestures for Alcohol Exposed group. Age is not associated with the use of operational and total gestures for the Non-exposed group. There is no relationship between age and the use of conceptual gestures for each group or for the total sample.
 - b. There is no correlation between IQ and the use of conceptual and operational gestures by the Alcohol Exposed and the Non-exposed groups.
 - c. Age is associated with the outcomes on the post-test. There is no relationship between IQ and the outcomes on the post-test.
5. The exploratory analysis also investigates whether conceptual gestures, age, and/or IQ predict learning the mathematical concept of equivalence. The results indicate that age and the use of conceptual gestures contribute separately to the learning process but when used in conjunction predict children's learning of equivalence.

A discussion of the findings in relation to the literature occurs in chapter six.

CHAPTER SIX

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

*“The most interesting information comes from children, for they tell all they know and then stop”
– Mark Twain*

6.1 INTRODUCTION

Prenatal alcohol exposure is a pervasive cause of developmental disabilities and learning problems that has been estimated to impact approximately one out of one hundred children in the United States and in South Africa (Olsen et al., 2009). The prevalence of children affected by prenatal alcohol exposure is comparable to or higher than the prevalence of other developmental disabilities such as Fragile X and Spina Bifida (Bertrand et al., 2004). However, according to the search of peer reviewed literature for this dissertation, only a few studies have examined interventions for children affected by prenatal alcohol exposure as compared to other developmental disabilities with similar prevalence rates (Bertrand, 2009).

The findings from this study contribute to the understandings of the learning difficulties of a population at high risk for academic failure in the United States and in South Africa that has had minimal consideration in the literature (Kable & Coles, 2004a; Bertrand, 2009; Ryan & Ferguson, 2006).

Many children affected by prenatal alcohol exposure neither qualify nor have access to specialized instruction due to regulations or lack of available services and receive their education within a general education or mainstream setting (Stade et al., 2006; Ryan & Ferguson, 2006; Fletcher et al., 2003).

The results from this study provide instructors who teach in general education classroom settings information as to how children affected by prenatal alcohol exposure learn a specific mathematical concept. The findings support that observing the use of gestures may be a viable option to assess how children affected by prenatal alcohol exposure construct knowledge. The determination of children's level of learning through their use of gestures would enable

instructors to intervene during instructional periods to prevent learning inaccuracies and limit the chance for later failure.

Chapter six presents the conclusions and the discussion of the findings in relation to the literature reviewed for this study. Also, chapter six presents the study's limitations, the educational implications, and recommendations. The chapter concludes with suggestions for future research.

6.2 STUDY CONCLUSIONS

This exploratory study investigated whether children affected by prenatal alcohol exposure used gestures to facilitate learning the concept of equivalence as compared to children whose development was considered unremarkable. The study examined the influence of gestures used by children affected by prenatal alcohol exposure while learning through three questions and related hypotheses. The conclusions are discussed in the next sections.

6.2.1 Primary study question and hypothesis one

The cognitive impairments associated with the effects from prenatal alcohol exposure vary from global intellectual delays to specific deficits in encoding, working memory, executive functioning, visual-spatial processing, integrating verbal and visual information, and processing numerical information (Dodge et al., 2008; Mattson et al., 2010). Due to impairments in one or more of these areas, many children with FAS experience difficulties learning mathematics (Howell et al., 2006; Rasmussen & Bisanz, 2009).

The study investigated the primary question to determine whether children with FAS or pFAS would have difficulties learning the mathematical concept of equivalence as compared to a matched control group. Based upon previous studies it was considered feasible that the children affected by prenatal alcohol exposure would exhibit overall poorer performance in mathematics (Howell et al., 2006; Rasmussen, & Bisanz, 2009).

The primary study question stated: Will children affected by prenatal alcohol exposure demonstrate a poorer understanding of equivalence as compared to children without a clinical

diagnosis? The question was examined through hypothesis one that stated children in the Alcohol Exposed group will have lower scores on the pre-test and pos-test than the Non-exposed group.

The results partially supported hypothesis one. The comparison of the pretests indicated that the children in the Alcohol Exposed group had a similar understanding of equivalence as the Non-exposed group. This was unexpected given that research suggested that children and adolescents affected by prenatal alcohol exposure exhibit lower scores on mathematic achievement measures (Howell et al., 2006).

Though the participants had similar scores on the pre-test, the children in the Alcohol Exposed group had lower scores on the post-test as compared to the Non-exposed group. This finding was commensurate with studies indicating that children with FAS demonstrate poorer performance in mathematics as compared to age matched peers (Howell et al., 2006; Rasmussen & Bisanz, 2009).

Further analysis of the pre-test and post-test indicated that the children in the Alcohol Exposed group showed no changes in learning after participating in the intervention. In contrast, the children in Non-exposed group demonstrated a statistically significant increase in their post-test scores as compared to their pre-test scores. It is important to note that both groups were considered evenly matched by age, intellectual functioning, and exposure to a similar quality of education. It is likely that the lack of learning by the children in the Alcohol Exposed group would be attributed to the deficits in processing associated with the effects from prenatal alcohol exposure (Kodituwakku, 2009; Santhanam et al., 2009; Jacobson et al., 2011). Therefore, it is suggested that regardless of intellectual functioning, many children with FAS or pFAS exhibited difficulties learning mathematics and most likely would require instructional interventions.

The differences in gesture use in relation to learning mathematics were explored through the study's sub-questions and hypotheses and are discussed in the next sections.

6.2.2 Second study question and hypothesis two

Gestures have been shown to serve multiple functions during interpersonal exchanges and to facilitate learning in children with and without developmental disabilities (Alibali, 2005; Streeck,

2009; Karmiloff-Smith et al., 1997). As discussed in chapter three, children with Williams syndrome used gestures to support word retrieval but not to aid in the communication of ideas (Bello et al., 2004). In contrast, many children with Down syndrome used gestures to express their ideas given articulation difficulties associated with the disorder (Caselli et al., 1998). A consistent pattern of gesturing among populations with developmental disabilities has not been identified.

Typically developing children use gestures to support communication and learning. Children use gestures while learning mathematics to integrate previous knowledge with new information to develop concepts (Melinger & Kita, 2007; Hostetter et al., 2007; Perry et al., 1988). Studies suggested that observing children's use of gestures as they learn mathematics provides a glimpse into their thought transitions, spatial reasoning, concurrent activation of problem solving strategies, and their readiness to receive instruction (Ehrlich et al., 2006; Broaders, et al., 2007; Perry et al., 1988; Goldin-Meadow & Alibali, 2002; Goldin-Meadow, 2009).

Based upon studies of gesture use by children with developmental disabilities who exhibit similar cognitive profiles as children affected by prenatal alcohol exposure and studies into the functions of gesturing during while learning mathematics, it was surmised that children affected by prenatal alcohol exposure would use few representative gestures to assist with learning the concept of equivalence (Dodge et al., 2008; Ma et al., 2005; Willoughby, Sheard, Nash, & Rovers, 2008; Bello et al., 2004). This was examined through the second study question and hypothesis two.

The second study question stated: Do children affected by prenatal alcohol exposure use fewer conceptual gestures to explain their understanding of equivalence as compared to children without a clinical diagnosis? This was explored through hypothesis two that stated: Children in the Alcohol Exposed group will exhibit a lower number of conceptual gestures compared to the Non-Exposed group.

As predicted in hypothesis two, the results indicated that the children in the Alcohol exposed group used fewer conceptual gestures while learning to solve equivalence problems as compared to the Non-exposed group.

Unlike the children in the Non-exposed group, the children in the Alcohol Exposed group demonstrated a concrete, procedural understanding of equivalence that was ineffective in solving problems that deviated from common addition problem formats (Karmiloff-Smith, 1992; Perry et al., 1988).

It is possible that the low number of conceptual gestures used by the children in the Alcohol Exposed group reflected difficulties integrating abstract information to form concepts and to apply the information to solve problems presented in novel formats (McNeil & Alibali, 2004; Perry et al., 1992).

The third study question and hypothesis three investigated the relationship between the use of conceptual gestures and learning and are discussed in the next section.

6.2.3 Third study question and hypothesis three

Previous studies have shown that children who used representative gestures while learning to solve equivalence problems exhibited an increase in learning (Broaders, et al., 2007; Goldin-Meadow et al., 2008). Based upon this premise, the third study question was investigated.

The third study question stated: Will there be a correlation between the types of gestures used and the outcomes on the mathematics post-test? This question was examined through hypothesis three that stated: Children who demonstrate fewer conceptual gestures will score lower on the mathematical post-test.

Correlations were conducted to investigate the relationship between the use of conceptual gestures and the outcomes post-test for the total number of participants, as well as for the Non-exposed, and the Alcohol Exposed groups separately.

Overall the children's number of conceptual gestures was related to an increase in post-test scores. This finding was commensurate with previous studies indicating conceptual gestures facilitate learning of equivalence (Perry et al., 1988; Alibali & Goldin-Meadow, 1993; McNeil & Alibali, 2004; Broaders et al., 2007; Rittle-Johnson & Alibali, 1999). However, the influence of the number of conceptual gestures used by the children and their learning of equivalence differed when analyzed by group.

The findings suggested there was no correlation between the use of conceptual gestures and the outcomes on the post-test for the children in the Non-exposed group. Most likely this was due to the small number of children in the group. In contradiction to the studies reviewed for this dissertation, the results showed that children in the Alcohol Exposed group who used conceptual gestures showed a decrease in their post-test scores (Perry et al., 1988; Alibali & Goldin-Meadow, 1993). This suggested that the use of conceptual gestures by the children in the Alcohol Exposed group did not facilitate learning of equivalence.

It is unclear whether the relationship between the use of conceptual gestures and the decrease in post-test scores reflected the neurological deficits associated with prenatal alcohol exposure or some other confounding factor that interfered with learning. For example, it may be possible that the use of conceptual gestures increased cognitive demands therefore interfered with learning (Roebuck-Spencer & Mattson, 2004; Dodge et al., 2008; Goldin-Meadow, 2008). It may be suggested that the decrease in post-test scores in relation to the use of conceptual gestures may reflect the deficiencies in processing speed and integration of information associated with the effects from prenatal alcohol exposure (Mattson & Roebuck, 2002; Wozinak et al., 2011).

Also, it may be that the correlation between the use of conceptual gestures and the decrease in post-test scores of the children in the Alcohol Exposed group signified a transitional state of thought that would require direct instructional intervention to learn the concept of equivalence (Karmiloff-Smith, 1992; Perry et al., 1988; Perry et al., 1992).

Nevertheless, the findings indicated that gesturing influences learning in children affected by prenatal alcohol exposure. Further studies need to examine whether the use of gestures by children affected by prenatal alcohol exposure interferes and/or facilitates learning mathematics.

An exploratory analysis was conducted to investigate if age and IQ influenced the use of conceptual gestures and would predict children's learning the concept of equivalence. The conclusions are discussed in the next sections.

6.2.4 Exploratory analysis

An exploratory analysis was conducted to determine if age and IQ influenced the use of conceptual gestures and learning outcomes. Two questions were examined in the exploratory analysis.

6.2.4.1 Exploratory question one

The first exploratory question stated: Are there relationships between age, IQ, and the use of conceptual, operational, and the total number of gestures?

The findings suggested that age and IQ were not related to the use of conceptual, operational, and overall number of gestures for the total number of participants in the study. However, the findings indicated a relationship between age and the use of operational gestures and the total number of gestures used by the children in the Alcohol Exposed group. The results suggested that the older children in the Alcohol Exposed group used more operational gestures than the younger children.

Research has shown that children exhibited an increase in gesture use when activating more than one strategy to solve a problem (Perry et al., 1992; Goldin-Meadow et al., 1993; Goldin-Meadow, et al., 2009). It is possible that the older children in the Alcohol Exposed group who have had more experience with mathematics showed an increase of gestures as they attempted to access a larger repertoire of strategies to solve the problems as compared to younger children (Goldin-Meadow et al., 2009; Perry et al., 1988).

6.2.4.2 Exploratory question two

The second exploratory question stated: Are age, IQ and the use of conceptual gestures associated and predictive of children's learning the concept of equivalence?

The results indicated that only age was associated with outcomes on the post-test for the total number of participants. Age and the use of conceptual gestures were found to contribute separately to children's learning. However, combined age and the use of conceptual gestures

predicated the learning of equivalence. This suggested the conceptual gestures influences learning of the concept of equivalence.

A summary of the study's conclusions is presented in the next section.

6.2.5 Summary of the study's conclusions

The conclusions from the study are as follows:

- Children in the Alcohol Exposed group demonstrated no changes in their learning of equivalence after receiving instruction as compared to the Non-exposed group. This indicated that children in the Alcohol Exposed group showed were inefficient in their learning the concept of equivalence regardless of their cognitive functioning as compared to the control group.
- Children in the Alcohol Exposed group used fewer conceptual gestures as compared to the children in the Non-exposed group. Most likely, the limited use of conceptual gestures reflected weaknesses in concept formation, integration of information, and generalization of information. The weakness in concept formation reflected findings from previous studies that showed children with FAS exhibit deficits in executive functioning and concept formation (McGee et al., 2008; Ma et al., 2005; Mattson et al., 2006).
- The total number of participants who used conceptual gestures exhibited an increase in learning the concept of equivalence. This was consistent with previous studies suggesting that children use gestures to facilitate learning a mathematical concept (Alibali & Goldin-Meadow, 1993; Perry et al., 1988; Broaders et al., 2007).
- In contrast to the findings of children's use of gestures while learning a mathematical concept, children in the Alcohol Exposed group who used conceptual gestures exhibited a decrease in their post-test scores as compared to their pre-test scores. Gestures were shown to influence learning. However the results were unclear as to whether the use of conceptual gestures added to the cognitive demands of the task, interfered with the processing of information, or were related to other possible confounding factors (Dodge et al., 2009).

- Age and the use of conceptual gestures were not associated but contributed separately to the learning of equivalence. This suggested that older children who have had more experience with mathematics and who used conceptual gestures most likely would learn the concept of equivalence more efficiently than younger children or those who did not use conceptual gestures.

A discussion of the conclusions in relation to the literature on mathematics, children's gestures, and impact of prenatal alcohol exposure on learning occurs in the next section.

6.3 DISCUSSION

Mathematics requires the understanding of concepts and operations and the skills to analyze and solve problems efficiently (Kilpatrick et al., 2001). Children who are competent in mathematics are able to create representations of concepts and apply the information to solve a variety of problems (Rittle-Johnson & Alibali, 1999; Rittle-Johnson, et al., 2001; Kilpatrick et al., 2001).

As stated in chapter three, studies have suggested that the coordination of speech and gesture demonstrates the synthesis of thought processes (Kita, 2000; McNeill, 2005). Observing changes in children's thought processes through their coordination of speech and gesture would provide insight as to how they integrate information to form a concept (Goldin-Meadow, Singer, & Kim, 1999; Alibali & Goldin-Meadow, 1993; Perry et al., 1988).

Children affected by prenatal alcohol exposure often exhibit specific deficits in encoding, working memory, executive functioning, visual-spatial processing, integrating verbal and visual information, and processing numerical information (Dodge et al., 2008; Mattson et al., 2010).

Due to the impairments in one or more of these areas, many children with FAS exhibit difficulties forming concepts that can be generalized to solve problems (McGee et al., 2008; Aragon et al., 2008; Rasmussen & Bisanz, 2009). It is probable, according to the findings from this study, that gestures used by children affected by prenatal alcohol exposure reflected a concrete understanding of equivalence that was not generalized to solve a variety of problems (Karmiloff-Smith, 1992).

The next section discusses the differences in the mental representation of information while learning the concept of equivalence by children affected by prenatal alcohol exposure as compared to children with a typical developmental profile as observed through their gesture use.

6.3.1 Gestures, mental representations, and learning equivalence

Studies have shown that children who construct schematic mental representations of concepts were able to generalize the information to solve a variety of problems (Hegarty & Kozhevnikov, 1999). Schematic mental representations are developed from essential abstract pieces of information and integrated to form new knowledge (Hegarty & Kozhevnikov, 1999; Fauconnier, 1997). Schematic representations provide a framework of information that is accessible across knowledge domains (Hegarty & Kozhevnikov, 1999; Brainerd, 1977).

Mental representations that use discrete pictures often generate irrelevant details that interfere with the connection of the salient abstract pieces of information needed to create new concepts (Fauconnier, 1997). Studies have shown that children who create schematic representations of mathematical information are noted to be more efficient when solving mathematical problems than children who image pictorially or by separate features (Hegarty & Kozhevnikov, 1999; Fauconnier, 1997).

As indicated by the Information Packaging Hypothesis discussed in chapter three, observing children's gestures gives a glimpse as to how they organize and link information during the learning process to form new concepts (Kita, 2000; Melinger & Kita, 2007; Perry et al., 1988; Alibali & Goldin-Meadow, 1993). Gestures used by children affected by prenatal alcohol exposure as compared to children without a clinical diagnosis were observed and analyzed to see if there were differences in the representation and construction of the understanding of equivalence.

In this study, operational gestures were considered to represent the procedures used to solve the problems (Alibali & Goldin-Meadow, 1993; McNeil & Alibali, 2004). The movements reflected the series of segmented steps based upon the mathematical symbols the children used to calculate the answer. Conceptual gestures were thought to represent the understanding of equivalence meaning the numbers on each side of the equal sign are the same (McNeil &

Alibali, 2005; McNeil & Alibali, 2004). The use of conceptual gestures provided a schematic representation that reflected the relationship between both sides of an equation. Comparing the differences in the use of conceptual and operational gestures by the children in the Alcohol Exposed group to the children in the Non-exposed group provided information as to how the children transformed information to develop the concept of equivalence.

The children in the Alcohol Exposed group used fewer conceptual gestures than the children in the Non-exposed group. This suggested dissimilarities in the mental representation of information between the two groups. Similar to the findings from earlier studies, conceptual gestures facilitated children's learning of the meaning of equivalence for the total number of participants. It is probable that the children who used conceptual gestures created a schematic representation of the concept equivalence that generalized across the problem formats (Hegarty & Kozhevnikov, 1999; Rittle-Johnson & Alibali, 1999; Alibali & Goldin-Meadow, 1993; McNeil & Alibali, 2004).

However, the children in the Alcohol Exposed group who used conceptual gestures exhibited decreases in their post-test scores. According to the Information Packaging Hypothesis, gestures contribute to the organization and integration of spatial and linguistic information into units to assist with conceptualization (Hostetter, et al., 2007; Alibali, et al., 2000; Alibali, 2005). Given the neurological impairments associated with the effects from prenatal alcohol exposure, specifically in the areas of integrating verbal and visual information and processing numerical information, it was likely that gesturing did not facilitate the integration of information to develop a schematic representation of concept of equivalence in the children affected by prenatal alcohol exposure (Ma et al., 2005; Roebuck et al., 2002; Mattson et al., 2010; Fryer et al., 2009; Wozniak et al., 2009; Wozniak et al., 2011).

The high number of operational gestures as compared to the low number of conceptual gestures used by children in the Alcohol Exposed group possibly indicated a concrete understanding of equivalence that was not transitioned into an abstract form for further use. According to the Representational Redescription (RR) model, knowledge is transformed through three phases. Through the three phases isolated pieces of information are re-encoded and transitioned into a format that is accessible by other domains (Karmiloff-Smith, 1992).

During the first phase of the RR model, children encode information as sequential steps that are stored as isolated components to be transformed through learning experiences (Karmiloff-Smith, 1992). Based upon the results from the gesture analysis from this study, the children in the Alcohol Exposed group exhibited a concrete, procedural understanding of equivalence as shown by the high number of operational gestures as compared to the low number of conceptual gestures that remained unchanged by the learning activity (Karmiloff-Smith, 1992; Rittle-Johnson & Alibali, 1999; Rittle-Johnson et al., 2001). The children in the Alcohol Exposed group were found to maintain their understanding of equivalence at the initial phase of the RR model where information is used in a single context and not generalized across problem formats (Karmiloff-Smith, 1992).

The following section discusses gesture use and encoding of mathematical problems.

6.3.2 Gestures and encoding mathematical problems

Encoding in this study referred to the representation of information to be used for processing or storage in memory (Willford et al., 2004; Mattson et al., 2006). Deficits in attending and processing visual stimuli would interfere with encoding the features including the subtle differences in mathematical problems. Children and adolescents affected by prenatal alcohol exposure are reported to have difficulties attending to and processing visual-spatial stimuli (Coles et al., 2002; Uecker & Nadel, 1996). Often children and adolescents with FAS are found to perseverate on irrelevant details and require extended time to respond to visual stimuli that would interfere with encoding of the structures of mathematical problems (Coles et al., 2002; Coles, 2001; McNeil & Alibali, 2004).

Studies have suggested a connection between conceptual understanding and the accurate encoding of an equivalence problem. McNeil and Alibali (2004) indicated that children use different methods to encode mathematical problems. Some children encode problems according to the perceptual similarities they have with familiar problems. Other children encode mathematical problems according to the relationship of the problem format to the concept. According to McNeil and Alibali (2004), children who displayed a single strategy in gesture were found to encode problems according to the perceptual features rather than connect the structure of the problem to the related concept. They were noted to exhibit limited skills to solve a variety of problem types.

The children in the Alcohol Exposed group demonstrated a procedural understanding of the concept of equivalence as shown by their pattern of gesture use. It is feasible that the children in the Alcohol exposed group encoded the mathematical problems according to the features that indicated a procedure rather than by the conceptual structure (Karmiloff-Smith, 1992; Alibali & Goldin-Meadow, 1993; McNeil & Alibali, 2004). This would interfere with linking concepts to procedures to develop problem solving techniques.

The next section discusses the use of conceptual gestures and problem solving techniques by children affected by prenatal alcohol exposure.

6.3.3 Gestures and problem solving

Many children affected by prenatal alcohol exposure exhibit deficits in executive functioning with specific weaknesses in the areas of concept formation and effective use of problem solving strategies (Vaurio et al., 2010; McGee et al., 2008). Deficits with encoding and with executive functioning would impede the selection and application of strategies to solve problems presented in different formats.

Studies suggested that children who use conceptual gestures to solve equivalence problems showed an increase in variability and flexibility of strategies to solve novel problems (McNeil & Aliabli, 2004; Alibali & Goldin-Meadow, 1993; Rittle-Johnson & Alibali, 1999). It is possible that high number of operational gestures as compared to the low number of conceptual gestures used by the children in the Alcohol Exposed group reflected limited concept formation and shifting of ideas. Deficits in these components of executive functioning would interfere with problem solving efficiency (McGee et al., 2008; Aragon et al., 2008).

Analysis of the strategies children used to solve to solve the different problem types was beyond the scope of this study. However, the children in the Alcohol Exposed group were found to add all of the numbers together regardless of the structure of the problem format. Given the deficits in executive functioning, it would be feasible to expect that children in the Alcohol Exposed group would use limited strategies and show difficulties shifting problem solving approaches to solve the different problem types (McGee et al., 2008; McNeil & Alibali, 2004; Rasmussen & Bisanz, 2009; Vaurio et al., 2008). The high number of operational gestures in comparison to the low number of conceptual gestures used by the children in the suggested rote memorization of

the steps to add numbers and a limited repertoire of problem solving strategies unchanged by the learning experience.

The next section discusses influence of the presentation of the learning exercise used in this study on learning.

6.3.4 Instructional presentation and learning

The learning activity required the children to view an instructional video and to solve three equivalence problems like those discussed in the video. The structure of the learning activity was an attempt to simulate a common classroom instructional sequence that discussed a concept, demonstrated the problem solving procedures, and provided children opportunities for independent practice (Hiebert et al., 1999). The results suggested that lessons that lectured and demonstrated the concepts and procedures to solve problems followed by independent practice did not provide the necessary level of instruction for the children in the Alcohol Exposed group to learn.

Because a goal of this study was to investigate whether there were differences in the use of gestures to facilitate learning between children affected by prenatal alcohol exposure and a control group, instructional interventions and prompts were not provided so as not to influence the participants' gestures and learning outcomes (Goldin-Meadow, Kim, & Singer, 1999).

The comparison of the pre-test scores showed that the children in the Alcohol Exposed group began the intervention with a similar understanding of equivalence as the children in the Non-exposed group. However, the children in the Alcohol exposed group showed no changes in learning after watching the instructional video and completing the practice exercise as indicated by their scores on the post-test.

Given the deficits with encoding and processing information associated with the effects from prenatal alcohol exposure, it is probable that the video lesson followed by solving problems independently did not provide adequate instruction. Specifically, the learning activities for this study did not provide the necessary instructor interaction, intervention, or the necessary amount of review and practice the children in the Alcohol exposed group needed to develop the

conceptual knowledge and related procedure (Bertrand, 2009; Coles et al., 2009; Kable et al., 2007).

Bertrand (2009) reviewed five intervention studies in the areas of social and peer interactions, behavior, parent-child interactions, safety, and mathematics designed for children affected by prenatal alcohol exposure. Intervention programs that included parent training and education on the impairments associated with the effects from prenatal alcohol exposure were found to be successful. The intervention programs used direct instruction and practice rather than relying on children affected by prenatal alcohol exposure, who may have impairments in encoding and integration of information, to learn through observation and incidental discovery (Bertrand, 2009; Kodituwakku, 2009).

Efficacy studies of the Math Interactive Learning Experience (MILE), a mathematics intervention program designed for children affected by prenatal alcohol exposure, indicated that children with FAS made gains in learning when provided direct instruction on ways to solve problems efficiently. It is important to note that MILE was implemented in a clinical setting and the findings cannot be generalized to a classroom setting (Kable et al., 2007; Coles et al., 2009; Bertrand, 2009; Kodituwakku, 2009).

An overview of the findings in relation to the literature is presented in the next section.

6.3.5 Summary of the discussion

A synopsis of the study's findings in relation to the literature on the effects from prenatal alcohol exposure, gestures, and learning is presented below.

- 1) The high number of operational gestures as compared to the low number of conceptual gestures used by the children in the Alcohol Exposed group indicated difficulties transitioning isolated pieces of information into abstract concepts and applied to solve a variety of problem types. The level of learning of the children in the Alcohol Exposed group appeared to be maintained at a rote state and was not transformed by the learning experience or their gesturing (Karmiloff-Smith, 1992).

- 2) The children in the Alcohol Exposed group most likely encoded equivalence problems based upon the isolated features represented by the mathematical symbols rather than the conceptual structure of the problem (McNeil & Alibali, 2004; Rittle-Johnson & Alibali, 1999). This would limit the application of conceptual information with procedural steps to develop flexible problem solving strategies.
- 3) The children in the Alcohol Exposed group demonstrated a limited repertoire of problem solving strategies that reflected their procedural and isolated representation of the information as compared to the children in the Non-exposed group (McGee et al. 2008; McNeil & Alibali, 2004; Rasmussen & Bisanz, 2009).
- 4) The children in the Alcohol exposed group exhibited no learning after viewing the instructional video and completing the practice activities. The structure of the lesson that discussed and demonstrated a concept, followed by independent practice with minimal student and instructor interactions was not conducive for learning for the children in the Alcohol Exposed group (Kable et al., 2007; Bertrand, 2009).

The next section discusses the limitations of this exploratory study.

6.4 LIMITATIONS OF THE STUDY

The findings from this study suggested that children affected by prenatal alcohol exposure exhibited difficulties representing abstract information needed to develop the conceptual understanding of equivalence in order to generalize the information to solve different problem types. There are factors related to the study design, the number of participants, and the gesture protocol that restrict the generalization of the findings to the larger population of children with FAS or pFAS.

- 1) The sample size for this study was sixteen children. The small sample size resulted in a large standard deviation of the means for the gesture types, the pre-test, and the post-test that would limit the detection of effects (Witte & Witte, 2000). A larger number of participants would be needed for statistical analysis in order to transfer the finding to the larger population of children with an alcohol related diagnosis.

- 2) The study implemented a quasi-experimental design that grouped participants according to their diagnosis of FAS, pFAS, or no clinical behavioral, mental health, learning or medical diagnosis. The assignments to groups based upon diagnosis might influence bias when analyzing the results (Shadish & Luellen, 2006). Future studies would need to assign participants randomly to groups that receive or do not receive an intervention to limit bias (Schoenfeld, 2006).
- 3) Information from the data indicated a difference in the use of gestures between the children in the Alcohol Exposed group and the children in the Non-exposed group. Investigation into the types of gestures used to solve a specific problem type was not conducted. Additionally, the gesture analysis needed to consider the matched or mismatched messages presented through the coordination of speech and gesture to pinpoint transitions of thought in children with FAS as compared to a control group (Alibali & Goldin-Meadow, 1993; Perry et al., 1988).
- 4) The ages of the children participating in the study ranged from 8.0 years to 13.0 years. The results from the study suggested that age is predictor for learning equivalence. The study needed to consider a more narrow age range or examine children within a particular grade level to limit the possible influence of age and experience on the learning outcomes (McNeil & Alibali, 2004; Alibali & Goldin-Meadow, 1993; Perry et al., 1988).
- 5) The findings of the patterns of conceptual and operational gestures used by the children in the study would not be able to transfer to other mathematical concepts such as fractions (Breckinridge Church & Goldin-Meadow, 1986; Donovan & Bransford, 2004).
- 6) Lastly, the gesture coding protocol was found to be complicated and time consuming. The coding protocol might not be useful for classroom teachers given the demands to instruct large groups of children.

Given the design of the study, the small number of participants, and the limitations, the findings would not be able to be discussed in relation to the larger population of children with FAS or pFAS. However, the results provide a starting point to examine how children affected by prenatal

alcohol exposure learn a concept in an academic subject identified to be a deficit (Jacobson et al., 2011; Rasmussen & Bisanz, 2009; Coles et al., 2009).

The educational implications from this study are presented in the next section.

6.5 EDUCATIONAL IMPLICATIONS

Systematic analysis of gestures provides insight into children's level of learning, and their readiness to receive instruction (Karmiloff-Smith, 1992; Hegarty & Kozhevnikov, 1999; Alibali & Goldin-Meadow, 1993; Perry et al., 1988). Awareness of children's gesturing during the learning process would provide teachers information as to when and how to adjust instruction to ensure learning success.

The next sections discuss the educational implications of observing the gesture use of children affected by prenatal alcohol exposure as they learn the concept of equivalence.

6.5.1 Gestures and learning equivalence

Conceptual understanding, encoding, variability of problem solving techniques, and learning are interconnected and correspond with the cognitive constructs of attention, executive functioning, and working memory (Dodge, et al., 2008; Roebuck-Spencer & Mattson, 2004; Mattson et al., 2006). Studies have shown that children affected by prenatal alcohol exposure often exhibit deficits in these areas that impede learning mathematics (Coles, 2001; Coles et al., 2002). The children in the Alcohol Exposed group exhibited weaknesses in the areas of concept formation, encoding, and effective selection and application of problem solving techniques as shown by their pattern of gesture use and their results on the post-test.

Teachers need to be attuned to the types and/or the lack of gestures used by children with FAS. The awareness of the gesturing patterns by children with FAS would provide teachers opportunities to assess children's level of learning and to address inaccuracies during the learning process. This might prevent subsequent learning difficulties caused by incorrect representation of information.

The analysis of gestures used by the children in the Alcohol Exposed group suggested that they maintained a concrete understanding of equivalence reflected by a series of memorized steps used to solve familiar problems. Children in the Alcohol Exposed group appeared to encode equivalence problems by features that overlapped with common addition problems. The imprecise linking of the problem features to the concept of equivalence possibly resulted in inefficient encoding of problem formats (McNeil & Alibali, 2004; McNeil & Alibali, 2005).

During classroom instruction, teachers would need to direct children affected by prenatal alcohol exposure to use gestures while learning to solve equivalence problems. This might include teaching children with FAS to run their hand under the mathematic problem, place hands under each side of the equation, or point to one side of the equation then to the other side of the equation while explaining how they solved the problem to provide an active representation of the concept in relation to the problem format. The verbal and visual representation would be integrated and applied to solve equivalence problems. Also, directing children with FAS or pFAS to use gestures would assist with directing attention to the essential problem features while as they explain the conceptual underpinnings to encode problems accurately (Broaders et al., 2007; Cook et al., 2008).

Children who are considered competent in mathematics demonstrate the understanding of the concepts in mathematics and use multiple strategies to solve problems (McNeil & Alibali, 2004). Teaching children with FAS to use conceptual gestures in coordination with language to explain their ideas might result in a shift from a procedural understanding to a flexible representation of equivalence that can be generalized to solve a variety of problem types (Goldin-Meadow et al., 2009; McNeil & Alibali, 2004; Karmiloff-Smith, 1992). Teaching children to use gestures during mathematics instruction would require frequent interactions between classmates and teachers (Ma, 1999).

6.5.2 Gestures and engagement to the learning process

Children in the Alcohol Exposed group showed no changes in their learning after watching the instructional video and completing the practice activity. Because a goal of the study was to investigate whether children with FAS or pFAS showed differences in gestures used while learning about equivalence as compared to children without a clinical behavioral, mental health,

or medical diagnosis, the examiner refrained from providing manual or verbal prompts or assistance to solve the problems.

Instruction was presented during a ten minute video that discussed the definition of equivalence and demonstrated the procedures to solve the equivalence problems. The children in the study were required to transfer the information learned from the video to solve equivalence problems. As shown by the findings in this study, the video presentation did not allow for student and teacher interaction and was not an effective instruction approach for children in the Alcohol Exposed group to learn. It is possible that given the deficits associated with the effects from prenatal alcohol exposure, the structure of the lesson did not engage the children in the learning process.

As indicated in the results from the MILE learning program, children affected by prenatal alcohol exposure require direct, interactive instruction to facilitate learning (Kable et al., 2007; Bertrand, 2009). Having children with FAS to use gestures while learning mathematics might aid in engaging children to the learning process and increase learning (Cook et al., 2008; Goldin-Meadow et al., 2009).

Impairments with integrating of verbal and visual information, encoding, and creating mental representations associated with the effects from gestational alcohol exposure interfere with learning mathematics (Willford et al., 2004; Mattson et al., 2006; Chasnoff et al, 2010).

Teaching children to use gestures might provide a conduit to work around the impairments associated with the effects from prenatal alcohol exposure to ensure accurate encoding, concept formation, and to increase engagement to lessons.

Recommendations for educational practices are presented in the next section.

6.6 RECOMMENDATIONS FOR INSTRUCTIONAL PRACTICES

Given the study's limitations, the findings from this study may not be generalized to the larger population of children affected by prenatal alcohol exposure. However, the results from this study in relation to the body of literature on the functions of gestures and interventions for

children with the effects from prenatal alcohol exposure provide a starting point to guide instructional practices.

1) Children affected by prenatal alcohol exposure would benefit from carefully scaffold mathematics instruction that provided frequent student and teacher interactions and discussions (Kable et al., 2007; Coles et al., 2009; Bertrand, 2009; Ma, 1999).

a. Instruction would need to demonstrate the connection of mathematical concepts to related procedures. Teachers would need to model how the problem was solved and give a thorough explanation of the thought processes. Instructional periods would need to provide opportunities for teachers and students to work through a variety of problems together and to discuss how the problems were solved.

Students need to be given time to present alternative strategies (Ma, 1999; Heibert et al., 1999). Class discussion regarding when and how to apply the strategy as well as the success, failure, and efficiency of the variety of problem solving strategies used by students would need to occur (Ma, 1999; Heibert et al, 1999).

b. The interactive lessons need to last longer than ten minutes. Preferably, interactive mathematical instruction needs to occur for most of the instructional period (Heibert et al., 1999). Independent practice would need to be allowed after the children affected by prenatal alcohol exposure exhibited a consistent understanding of the concept and related procedure during student and teacher interactions.

c. Teachers would need to use specific mathematical terminology and related gestures to illustrate thinking. This would provide an integrative message regarding the concept and/or procedure taught (Goldin-Meadow et al., 2009).

d. Teachers would need to direct children to explain their thought processes out loud as they solved problems. Children need to be directed to use their hands to demonstrate ideas as they discussed their ideas using targeted mathematical language. This would assist in the integration of the information to form concepts and increase attention to the relevant problem structures for accurate encoding (McNeil & Alibali, 2004; Goldin-Meadow et al., 2009).

- e. Children would need to explain their thought processes for problems that are correct as well as incorrect. This would provide multiple opportunities for teachers to assess children's level of learning. Also, inaccurate understandings may be corrected before extended practice has occurred thus limiting the amount of time required for re-teaching or remediation.
- 2) Teachers would need to attend to the children's use of gestures as they discussed their problem solving strategies or conceptual understanding. This would provide an immediate assessment of the children's learning and indicate need for immediate intervention. Suggestions for a brief gesture observation to be used by the classroom teacher are outlined below:
- a. Teachers would need to select a particular time during the instructional period to interact with a student or a small group of students to conduct a brief gesture observation.
 - b. Teachers would need to identify the concept, related vocabulary, and hand, arm, and other movements that would reflect the mental representation of the concept before conducting the observation.
 - c. During the observation, teachers would need to consider the children's use of mathematical language in relation to their manual movements to investigate if they conveyed similar or different messages (Kita, 2000; Goldin-Meadow et al., 2009; Alibali & Goldin-Meadow, 1993; Karmiloff-Smith, 1992). This would aid instructors in determining whether the children have a solid understanding of the mathematical concept that has been integrated to be applied across problem formats.

If children are in a state of conceptual transition, their gestures may not match the language they use. This would signify the need for direct instruction to ensure accurate concept formation (Perry et al., 1988; Goldin-Meadow et al., 2009).

If children's speech and gestures are coordinated and they are able to solve a variety of problem types accurately, most likely they have acquired a conceptual understanding of the concept that can be generalized (Karmiloff-Smith, 1992).

However, if the children exhibit a consistent message in speech and gesture but cannot solve a variety of problem types, this suggests a segmented level of learning (Perry et al., 1988; Goldin-Meadow et al., 2009). Teachers would need to provide direct instruction to help the children to develop the understanding of the concept and procedure to solve a variety of problems.

- d. Teachers would need to be aware of the lack of variety of gestures used by children with FAS or pFAS in relation to their accuracy for solving problems. Children affected by prenatal alcohol exposure who use a single type of gesture and are unable to solve a variety of problems may have acquired a concrete understanding of the concept and would benefit from further instruction (Alibali & Goldin-Meadow, 1993; Perry et al., 1992).
 - e. The information gathered from the gesture observations would enable teachers to adjust instruction based upon the children's level of learning. Teachers would be able to determine when to intervene by increasing interactions, when to introduce more complex problem formats, and when to allow children to work independently.
- 3) Children affected by prenatal alcohol exposure would need opportunities to explore a variety of mathematical problems related to a specific skill or procedure.
- a. Mathematical practice problems need to vary in format to prevent an over-reliance on a single strategy or the rote understanding of a procedure. This includes selecting worksheets that present a range of problem formats. Varying problem formats would provide opportunities to increase children's awareness of the problem structure and to guide selection of problem solving techniques (McNeil & Alibali, 2004; McNeil & Alibali, 2005).
- 4) Children affected by prenatal alcohol exposure would benefit from frequent review and repetition of previously learned skills in relation to new concepts and skills to see how they are used in various combinations.

As indicated earlier in this chapter, only a few studies found in the literature have investigated interventions for children affected by prenatal alcohol exposure. The studies have suggested that highly interactive and instructor guided programs that provide practice, review, and repetition were successful to increase learning (Coles et al., 2009; Bertrand, 2009). The findings from this study further support the need for children affected from prenatal alcohol exposure to receive interactive, guided instruction and interventions in their educational setting.

This dissertation concludes with suggestions for further research to understand the gesturing patterns of children impacted by prenatal alcohol exposure while learning mathematics.

6.7 SUGGESTIONS FOR FUTURE RESEARCH

Recommendations for areas of future research regarding gesture use by children affected by prenatal alcohol exposure while learning mathematics are as follows:

- 1) This exploratory study investigated the difference in the number of conceptual gestures and operational gestures used by children affected from prenatal alcohol exposure as compared to children whose development was considered to fit within a typical profile. Further research is needed to investigate the impact of the gesturing by children with FAS. Specifically additional research is needed to examine the types of messages conveyed through the matched (concordant) or mismatched (discordant) gesture and speech units (Alibali & Goldin-Meadow, 1993; Perry et al., 1988). This would provide information as to how children with FAS or pFAS transform information to form new concepts and problem solving strategies.
- 2) Methodological factors need to be considered when investigating the impact of gesturing by children with FAS or pFAS while learning mathematics. The factors include but are not limited to the following suggestions:
 - a. Studies investigating gesturing by children with FAS and mathematics need to consider a specific grade level or a more narrow age range to control for the impact of experience on learning.

- b. Studies need to assign participants randomly to an intervention group or groups and/or to a control group to limit bias.
 - c. Studies need to have a larger number of participants to determine statistical significance.
 - d. In addition, it might be beneficial to examine gesture use while learning a concept across age levels to investigate whether gesturing by children with FAS changes as they develop. This would provide information as to whether gesturing influences generalization as material becomes more complex as children progress through grade levels.
- 3) Studies need to examine whether teaching children with FAS to use specific types of gestures during the learning process is a useful strategy to support concept formation in mathematics. It is possible that teaching children with FAS to use gestures might tax cognitive systems compromised by the effects from prenatal alcohol exposure (Coles, 2001; Burden, Jacobson, & Jacobson, 2005).
- 4) Studies investigating gesture use often have been conducted in a clinical setting on a one-to-one basis with an individual. Investigation as to whether children use gestures differently in a classroom setting as compared to a clinical setting would provide information to develop possible gesture observation protocols for teachers.
- 5) Future studies investigating gesture use by children with FAS need to examine other mathematical topics or domains such as fractions, measurement, and using mental rotation to solve problems. This would give researchers a better understanding as to how the neurological impairments associated with the effects from prenatal alcohol exposure interfere with learning mathematics to guide the development of effective instructional interventions.

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Appendix A

3 November 2009

Dear Caregivers and Legal Guardians,

The Fetal Alcohol Center at the Marcus Autism Center (formerly the Marcus Institute) would like to tell you about an opportunity to participate in a research study. **The research study is to learn more about math problems of children with Fetal Alcohol Syndrome (FAS) or Partial Fetal Alcohol Syndrome (pFAS).**

The study is to see how children, ages 8 to 12, use gestures to learn math. **We are hoping to learn more about math difficulties of children with FAS or pFAS and to find ways to teach math to children with FAS or pFAS better.**

The study will require two (2) visits to the FAS Center at Marcus.

First Visit (Session will last 2 hours)

- You and your child will meet with Molly Millians, Special Educator with the FAS Center. Ms. Millians will answer any questions you have about the study.
- Your child will complete a math worksheet on equivalence.
- Your child will watch a 15-minute video on equivalence.
- Your child and Molly Millians will solve three math equivalence problems. Your child will be videotaped while solving the problems.

Second Visit (Session will last 1 hour)

- You and your child will be asked to return to the FAS Center 1 week after the first visit. You will meet with Molly Millians on your second visit.
- Your child will complete another worksheet on equivalence. This is to see how much your child learned.

You will be provided \$10.00 each session for travel expenses to the FAS Center for this study.

Ms. Millians will follow-up this letter with a telephone call to give more information and to answer any questions. Please feel free to contact her at **(404) 785-9451** or by e-mail at molly.millians@choa.org if you would like more information.

We hope you will consider this opportunity to learn more about how children with FAS or pFAS learn math.

Sincerely,

Molly Millians, M.Ed

Appendix B

Study No.: IRB00013471

Emory University IRB
IRB use only

Document Approved On: 11/23/2010
Project Approval Expires On: **11/22/2011**

Emory University School of Medicine **Consent to be a Research Subject**

Title: *A Needs Analysis of Gesture Use of Children with Fetal Alcohol Syndrome during Mathematics Instruction*

Principal Investigator: *Claire Coles, Ph.D.; Co-investigator, Molly Millians, M.Ed.*

Introduction/Purpose:

Your child is being invited to participate in this research study. The purpose of this study is to see if children with FAS use gestures to help them understand math. The results from this study will provide information to help us understand the mathematic difficulties of children with FAS and to help support their learning.

We will ask children with a diagnosis of Fetal Alcohol Syndrome (FAS) or Partial Fetal Alcohol Syndrome (pFAS) and children without an alcohol related diagnosis to participate. This is to compare the results to see if there are differences in learning between children with FAS and children without a diagnosis. Sixteen children will be asked to participate. The Primary Investigator for this study is Claire Coles, Ph.D., Director of the Fetal Alcohol Syndrome Center at the Marcus Autism Center. The Co-Investigator is Molly Millians, M.Ed., Special Educator of the Fetal Alcohol Syndrome Center at the Marcus Autism Center.

Before you agree to participate in this study, it is important to understand the information in this form. Please ask as many questions as you need to be sure you understand what you and your child will be asked to do.

Study Procedure:

The study will require two hours of your time. We will ask you to attend two sessions. Each child will work one-to-one with Ms. Millians. The sessions will occur at the Marcus Autism Center.

In the first session, your child will take an arithmetic test. Your child will solve several arithmetic problems. We want to see how much your child knows about the meaning of the equals sign. The equals sign means that the amounts on both sides of the equals sign are the same or equivalent. The problems on the test will be like problems given at school.

After finishing the first test, your child will watch a short video. The video will last 15-minutes. The video will teach about the meaning of the equals sign. Following the video, your child with help from a researcher will practice solving problems like the ones on the first test and shown on the video. Your child will explain how he or she solves each of the problems. Your child's explanations will be videotaped. Your child's use of gestures will be analyzed from the video.

The second session will be one week after the first session. Your child will be asked to complete another arithmetic test. Your child's scores on the first test will be compared to the scores on the second test. This is to see how much your child learned. Your child will not receive a grade on either test.

Risks:

There are no known risks associated with this study. There may be unanticipated risks.

Benefits:

Taking part in this research study may not benefit your child personally. The information your child provides however will add to our knowledge about how children with FAS or pFAS learn math.

Confidentiality:

All information will be kept strictly confidential to the extent allowed by the Health Insurance Portability and Accountability Act (HIPAA). Neither your name nor your child's name or identifying information will be revealed in any connection with this study. Identification numbers will be used in place of your name and identifying information. The identification numbers are only used in this study. Your name, your child's name, or other identifying information will not be used in any presentation or publication.

The video of your child's problem solving activity will be downloaded onto a computer to analyze. Passwords will be placed on the computer to protect the data. The computer will not be connected to the internet or to a network. Only the Researchers (those who are conducting the study) will have the passwords to access the video and the data. Your child's video will not be used in any publication or presentation.

If we become aware of any situation that places your child's safety at risk, such as abuse or neglect during this study, we are required by State law to report this information to the Department of Family and Children's Services.

Confidentiality and Protected Health Information (PHI):

There is a federal law [(45 CFR 46.116(a)(5)] called the Health Insurance Portability and Accountability Act (HIPAA). This law requires us to tell you how we will keep your files confidential. It was enacted to protect the privacy of your health information. This law says that certain information about you and your child is now "**Protected Health Information (PHI)**." PHI is any health information that identifies you or your child or that can reasonably be used to identify you by the person to whom it is provided.

Because of the Health Insurance Portability and Accountability Act (HIPAA), and before we can use or disclose your PHI, we must provide you with information about what PHI will be used, and how it will be used and disclosed. This section provides you with this information. This section will tell you what PHI the Researchers will review; who will collect the PHI; who will use the PHI, with whom it will be shared and the purpose of each use or disclosure; the expiration date or event, if any, after which we won't use or disclose your PHI any more; and your rights under

HIPAA to ask us not to use your PHI any more. If you decide to participate in this research, then you will be agreeing to let the Researchers and any other persons, companies or agencies described below to use and share your PHI for the study in the ways that are described in this section. Please review this section very carefully.

What PHI will the Research Team Use:

The Researchers will look at the medical records already at Marcus. The Researchers will look at your child's medical history. This is to determine if your child received a diagnosis of FAS. The Researchers will look at the results from any psychological or developmental tests regarding your child. They will look at your child's education records including educational placement, special education services, progress reports, and attendance records. This information will be recorded on a separate form. This will be called the "abstracted information."

To protect the privacy of your and your child's information, the Researchers will use identification numbers in place of the abstracted information. The identification numbers will be unique to this study. The identification numbers and codes will be used in place of your child's name, scores from psychological or developmental testing, diagnoses, and school information. The information will be kept on a computer with password protection. The computer will not be configured for internet or network access. This is to prevent electronic access to the information. Only the Researchers will have access to the information and the passwords.

Your child will be video taped as he or she does the practice activity. The Researchers will count and code your child's gestures. This will help us investigate how they learn. Your child's videotape will be downloaded on to a computer to finish analyzing. Access to the video on the computer will be password protected. Again, only the Researchers will have access to the video. Your child's video will not be used in any publication or presentation.

The abstracted information and the videotape will be stored in a locked cabinet at the Marcus Institute. When the study is completed, the videotape and the abstracted information will be destroyed. This will prevent access to any of the information that might identify you or your child's connection to this study.

Who will collect the PHI:

The PHI will be collected by Molly Millians, M.Ed. and/or Claire Coles, Ph.D.

Who will Use the PHI; With Whom will it be Shared; and For What Purpose(s) Will it be Used or Shared:

If required by law or regulations, the Researchers may share your PHI with the following persons, agencies, or companies. Please review this section carefully since you will be giving the Researchers permission to provide this information to carry out the study. Government agencies that make rules and policies about how research is done, including the Office for Human Research Protections (OHRP) may need to look at the study records that contain PHI. This includes the Emory University Institutional Review Board (IRB). In addition, records may be disclosed if there is a court order. The groups and the purposes for viewing the information are listed in the Table below.

<u>Person/Entity</u>	<u>Purpose</u>
Researchers	To conduct the study entitled, "A Needs Analysis of gesture use during Mathematics Instruction in Children with FAS" the purpose is to investigate the impact of gesture use to support learning a mathematical concept and to provide information to develop educational interventions for children with an alcohol related diagnosis
Emory University and departments charged with oversight of research, including the IRB.	To monitor safety, and compliance with applicable laws, regulations and University policies and procedures.

We will not use or disclose your records in any manner other than the ways we have described. We will keep your records private to the extent possible. We will do this even if an outside review of your records occurs. We will use an identification number used for this study only on records in place of your and your child's name where we can.

Expiration Date or Event:

When the study is complete, your Authorization to use the PHI will end. We will destroy the videotapes, your child's tests, and the abstracted information. All identifiers will be removed from the information making it impossible to link you to the study.

Your Right Under HIPAA to Revoke Your Authorization and Ask Us Not to Use Your PHI**Any More:**

Giving the Researchers your authorization to use and share your child's PHI is voluntary. At any time, you may choose to revoke your authorization for the Researchers to use and share your child's PHI. Revoking your authorization will not affect your child's current or future health care or services. There will be no penalty or loss of any benefits to which you or your child are otherwise entitled if you revoke your consent.

If you decide that you want to revoke your authorization for us to use your child's PHI you must give us written notice. You may do so by completing and signing the revocation letter that you receive with your copy of this Combined Informed Consent/HIPAA Authorization form. Once you complete the letter, you will need to give it to the Researchers. If you need another copy of this form, you may ask the Researchers to provide you with one. You may call (404) 419-4251 to get a new copy. Once we receive your letter revoking permission to use your child's PHI, we will not make any other use of your child's PHI or share it with anyone else. However, even after you revoke authorization, we will provide any governmental or University personnel, departments or committees with any data that they may need in order to comply with/or investigate adverse events or non-compliance with any applicable laws, regulations or University policies.

Compensation:

You will receive \$10.00 for each session (a total of \$20.00). This to help with travel costs to the Marcus Institute. There will be no other compensation provided for participating in this study.

Contact Persons:

If you have any questions, concerns, or complaints about this study you may call Molly Millians. Call Dr. Coles, if you have been harmed from being in this study. Also, call the Emory University Institutional Review Board if you have any questions about your and your child's rights as a participant in this research study.

Their telephone numbers are

Dr. Claire Coles (404) 419-4262

Ms. Molly Millians (404) 419-4251

Emory University Institutional Review Board: (404) 712-0720 or toll free at 1-877-503-9797.

New Findings:

We may learn new things during the study that you may need to know. We can also learn about things that might make you want to stop participating in the study. If so, you will be notified about any new information.

Voluntary Participation and Withdrawal:

Your child's participation in this study is voluntary. You have the right to refuse to be in this study. You can stop at anytime after giving your consent. The decision to stop will not affect you and your child's current or future medical care or any other benefits to which you are otherwise entitled in any way. The investigators may stop you from taking part in this study at any time if they decide it is in your best interest, or if you do not follow the study instructions.

Permission to Videotape:

I _____, the undersigned, give permission to the FAS Center at the Marcus Autism Center to videotape my child for this study.

We will give you a copy of this consent form to keep.

If you are willing to volunteer for this research, please sign below.

Subject's name (Please Print)

Parent or Legal Guardian

Date/Time

Person Obtaining Consent

Date/Time

Appendix D

Study No.: IRB00013471

Emory University IRB

Document Approved On: 11/23/2010

IRB use only

Project Approval Expires On: **11/22/2011**

Written Assent Document for 11-16 year olds

Project Title: A Needs Analysis of Gesture Use of Children with Fetal Alcohol Syndrome during Mathematics Instruction

We are asking if you are willing to be in a research study. This means, we will ask you for your help to study how children use gestures to learn math.

To do this, we will ask you and _____ (Caregiver) to come to our office to do some math activities with a researcher.

- 1) First, you will take a short math test. You will solve some problems like the ones you have at school. We will not give you a grade.
- 2) Next, you will watch a video that teaches about math problems like the ones on the test.
- 3) After the video, you will practice solving math problems like the ones you saw. A researcher will help you solve the problems. You will be videotaped as you solve the problems. Only the researchers will see your video.
- 4) One week later, we will ask you to come back. You will take another short math test. This is to see how much you learned. We will not give you a grade.

You can say “yes” or “no” to be in this study. Your doctors, your parents, or your teachers cannot make you be in the study if you don’t want to be in it. If you say “yes” to be in the study but change your mind about it later, you can stop being in the study. No one will be mad at you whatever you say.

If you want to be in the study, sign here.

Participant

Date/Time

Appendix E

Study No.: IRB00013471

Emory University IRB

Document Approved On: 11/23/2010

IRB use only

Project Approval Expires On: **11/22/2011**

Documentation of Assent from Pediatric Subjects

Project Title: A Needs Analysis of Gesture Use of Children with Fetal Alcohol Syndrome during Mathematics Instruction

Subject age: _____ years.

For subjects in this study who are minors, one of the following Pediatric Assent sections must be satisfied. Place a checkmark beside the method used.

1. _____ (<6 years) NO ASSENT REQUIRED

2. _____ (ages 6-10) VERBAL ASSENT

This study has been explained to this child in an age-appropriate manner. The child has asked questions, verbalizes understanding of the information, and provides verbal assent.

_____	_____	_____
Person Soliciting Assent	Date	Time

3. _____ (ages 11-16) WRITTEN ASSENT See attached Written Assent document.

4. _____ (age 17) READ/SIGN MAIN CONSENT DOCUMENT WITH GUARDIAN

5. _____ (any age) UNABLE TO PROVIDE ASSENT

In my opinion, this child cannot give informed assent.

Reason(s): _____

_____	_____	_____
Person Soliciting Assent	Date	Time

_____	_____	_____
Principal Investigator	Date	Time

Appendix F

Study No.: IRB00013471

Emory University IRB

Document Approved On: 11/23/2010

IRB use only

Project Approval Expires On: **11/22/2011**

Claire D. Coles, PhD and Molly Millians, M.Ed.

Fetal Alcohol Syndrome Center

Marcus Autism Center

1920 Briarcliff Road NE

Atlanta, Georgia 30329

Regarding Project: A Needs Analysis of Gesture Use of Children with Fetal Alcohol Syndrome during Mathematics Instruction

Dear Dr. Coles,

I want to end my child's participation in the research study that is named above. In addition to ending my child's participation I would like to [choose one of the following options]:

REVOKE MY AUTHORIZATION FOR THE RESEARCHERS TO COLLECT AND USE MY CHILD'S INFORMATION:

_____ My child will not actively participate in the study, and I revoke my authorization to permit the researchers to collect and use any more information about my child. I understand and agree that in certain circumstances the researchers may need to use my information even though I have revoked my authorization, for example, to let me know about any safety concerns, or to make any required reports to governmental regulatory agencies.

CONTINUE MY AUTHORIZATION FOR THE RESEARCHERS TO COLLECT AND USE MY CHILD'S INFORMATION:

_____ My child will not actively participate in the research study any more, but the researchers may continue to collect and use information from my child's medical record as needed for the research study, but only for the reasons discussed in the consent form that I signed.

I understand that the researchers will respond to this letter by letting me know that they have received it.

Sincerely,

Signature of Study Participant ----Date

Appendix G**(Pre-test)**

Worksheet #1

Name: _____

1) $4 + 7 + 2 = \underline{\quad}$

9) $2 + 8 + 1 = \underline{\quad} + 1$

2) $6 + 1 + 2 = 6 + \underline{\quad}$

10) $3 + 2 + 9 = \underline{\quad}$

3) $7 + 3 + 2 = \underline{\quad} + 2$

11) $0 + 4 + 7 = \underline{\quad}$

4) $8 + 6 + 3 = \underline{\quad} + 3$

12) $6 + 9 + 4 = 6 + \underline{\quad}$

5) $4 + 2 + 8 = 4 + \underline{\quad}$

13) $4 + 3 + 7 = \underline{\quad} + 7$

6) $5 + 3 + 4 = \underline{\quad}$

14) $5 + 8 + 2 = 5 + \underline{\quad}$

7) $1 + 7 + 8 = 1 + \underline{\quad}$

15) $1 + 4 + 7 = \underline{\quad}$

8) $0 + 2 + 5 = \underline{\quad} + 5$

Appendix H**(Post-test)**

Worksheet #2

Name: _____

1) $2 + 7 + 5 = \underline{\quad}$

9) $3 + 2 + 8 = \underline{\quad} + 8$

2) $7 + 1 + 2 = 7 + \underline{\quad}$

10) $1 + 7 + 6 = \underline{\quad}$

3) $2 + 6 + 3 = \underline{\quad} + 3$

11) $0 + 5 + 8 = \underline{\quad}$

4) $8 + 2 + 9 = \underline{\quad} + 9$

12) $6 + 2 + 9 = 6 + \underline{\quad}$

5) $5 + 4 + 6 = 5 + \underline{\quad}$

13) $8 + 1 + 4 = \underline{\quad} + 4$

6) $6 + 1 + 8 = \underline{\quad}$

14) $2 + 4 + 5 = 2 + \underline{\quad}$

7) $4 + 9 + 4 = 4 + \underline{\quad}$

15) $9 + 2 + 3 = \underline{\quad}$

8) $5 + 7 + 0 = \underline{\quad} + 0$

Try these:

$2 \times 4 \times 3 = 2 \times \underline{\quad}$

$5 \times 3 \times 1 = \underline{\quad} \times 1$

$4 \times 1 \times 2 = \underline{\quad}$