

Transfer of Learning in
Children with Fetal Alcohol Spectrum Disorder

by

Robert John McInerney
B.Sc. Honours, McMaster University, 1996
M.Sc., University of Victoria, 2001

A Dissertation Submitted in Partial Fulfillment of the
Requirements for the Degree of

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Abstract

Objective: Fetal alcohol spectrum disorder (FASD) is a permanent developmental disorder that can occur if women drink alcohol while pregnant. Despite substantial variability in FASD as a population, anecdotal evidence and clinical reports suggest that affected individuals have difficulty learning from experience and generalizing information from one situation to another, and tend to make the same mistakes over and over. Consistent with research in cognitive and educational psychology, these difficulties were conceptualized as impairments in “transfer of learning.” This dissertation sought to measure transfer of learning using three experimental transfer measures and an exploratory parental transfer questionnaire. In addition, performance on the experimental transfer measures was investigated in relation to aspects of executive functioning, because abilities thought to underlie successful transfer bear much resemblance to aspects of executive functioning.

Participants and Methods: The sample included 16 children diagnosed with FASD and 16 age- and gender-matched control children. Children were screened for intelligence and excluded if their performance on both Vocabulary and Matrix Reasoning

from the WISC-IV fell below the 9th percentile. Children completed three transfer tasks: (1) a novel, experimental modification of the Tower of Hanoi involving nested plastic cups and Tupperware containers; (2) a variation of Chen's (1996) Bead Retrieval Problem; and (3) the Purdue Pegboard. Participants also completed three executive functioning tasks that were selected to measure concept formation and flexibility: (1) Picture Concepts from the WISC-IV; (2) the D-KEFS Color-Word Interference Test; and (3) the Visual-Verbal Test. In addition, parents or caregivers completed an exploratory questionnaire designed to assess children's transfer of learning abilities in everyday life, along with the ABAS-II, a standardized measure of adaptive functioning.

Results: Children with FASD displayed significantly weaker performance on the Transfer Condition of the Tower of Hanoi, even after controlling for intelligence. Group differences were not observed on the Bead Retrieval Problem or on the Purdue Pegboard.

On the measures of executive functioning, control children outperformed those with FASD on all measures before controlling for intelligence. In addition, there was a significant relationship between the Tower of Hanoi and the Visual-Verbal Test; the latter was the only executive functioning task related to transfer of learning. This finding, however, did not persist when intelligence was accounted for.

After controlling for intelligence, significant group differences also were found on parental ratings of everyday transfer ability and on more complex aspects of adaptive functioning.

Conclusions: Two out of four newly created measures in this exploratory dissertation provided partial support for weak transfer of learning in FASD. This was observed on the modified Tower of Hanoi, which shared an identical structure between conditions but differed in surface appearance. Parental ratings also indicated weak transfer of learning, although in children with FASD, these reports did not correlate with transfer abilities on the Tower of Hanoi. Children with FASD also demonstrated weak executive functioning, but this weakness was moderated significantly by intelligence. The relationship between transfer of learning and executive functioning appeared to be driven primarily by cognitive flexibility, although this relationship also was moderated by intelligence.

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Dedication

To my parents, Ron and Nelly, who are, and always have been, my biggest fans,
and who have always loved me and supported me unconditionally.

To Brigitte, my partner and best friend,
who took this journey with me step for step.

To the memory of my grandmothers, Dorothy and Elene,
who would have been so proud of me.

And to Mondays with Wally.

Introduction

Alcohol, when ingested by a pregnant woman, is able to cross the placenta and harm the developing fetus. Historical accounts of this understanding, in rudimentary form, date back thousands of years. In Judges 13:7 women were admonished, “Behold, thou shalt conceive, and bear a son; and now drink no wine nor strong drink...” In the early 1600s, Robert Burton is noted to have said, “Foolish, drunken, or haire-brained women [for the] most part bring forth children like unto themselves, morose and feeble” (Abel, 1999). In the mid-1700s during the “gin epidemic” in England, the Royal College of Physicians warned against alcohol consumption during pregnancy, noting that alcohol is “too often the cause of weak, feeble, and distempered children, who must be, instead of an advantage and strength, a charge to their country” (Warner, 2003).

A description of the harmful effects of prenatal alcohol exposure first appeared in the medical literature in 1968, when a group of French researchers documented the findings of 127 children born to mothers who drank alcohol while pregnant. These researchers noted the “highly distinctive appearance of children of alcoholic parents, particularly alcoholic mothers. . .” (Lemoine et al., 1968, as cited in Mattson & Riley, 1998). Widespread interest in the effects of prenatal alcohol exposure laid dormant until 1973, when Seattle researchers Jones and colleagues published two studies in which they described a triad of malformations that, collectively, they termed the “fetal alcohol syndrome” (FAS; Jones, Smith, Ulleland, & Streissguth, 1973; Jones & Smith, 1973).

Epidemiologically, prenatal alcohol exposure is a serious problem. It is the leading cause of mental retardation in the Western world (Stratton, Howe, & Battaglia, 1996). Current incidence is estimated at 0.97 cases per 1,000 live births in the general population; however, the incidence in African American and Native American populations is much higher, estimated at 2.29 cases per 1,000 live births (Abel, 1995; Stratton et al., 1996). This amounts to between two- and twelve thousand FAS births per year in the United States (Stratton et al., 1996). To date, there are no data on the incidence of FAS in Canada; however, estimates place it at 1-2 cases per 1,000 live births, which translates to about 350 children born each year (Dzakpasu, Mery, & Trouton, 1998). The financial costs associated with FAS are high to the affected individual, to families, and to society. The Canadian Centre for Substance Abuse has estimated that it costs \$1.4 million dollars in extra health care, education, and social services to care for one child with FAS (Square, 1997).

As will be reviewed in detail later, children exposed prenatally to alcohol typically have difficulties across several domains of cognitive, behavioural, social, and adaptive functioning. Yet, there is tremendous variability within this population. Indeed, studies examining intellectual ability in FASD have documented individuals with severe mental retardation, and others with solidly average intelligence. There are observational accounts and anecdotal evidence, however, that even in the context of broadly average-range intelligence, children exposed prenatally to alcohol have difficulty transferring and/or generalizing learning from one situation to another. The primary goal of this dissertation is to empirically investigate these anecdotal accounts using three

experimental transfer of learning measures along with a new parental transfer of learning questionnaire, and to investigate whether transfer of learning is related to aspects of executive functioning.

The first part of this dissertation presents a general review of the sequelae associated with prenatal alcohol exposure. The second part presents an overview of transfer of learning and its relevance to everyday life. Finally, the third section proposes various methods of measuring transfer of learning using a combination of standardized and experimental tasks.

Prenatal Alcohol Exposure: A Spectrum Disorder

There is enormous variability in how prenatal alcohol exposure affects any given individual. In consequence, the sequelae of prenatal alcohol exposure are conceptualized as falling along a spectrum. At the severe end of the spectrum lies infant death and full FAS, as detailed by Jones and Smith (1973). The full FAS is defined as a triad of malformations that includes: (1) growth deficiency, including microcephaly; (2) central nervous system (CNS) disorders; and (3) a distinctive pattern of abnormal facial features. Yet, many children with heavy prenatal alcohol exposure do not meet the criteria for full FAS. Typically, they lack the abnormal facial features but have the associated brain damage (Mattson, Schoenfeld, & Riley, 2001). These children have been labelled less precisely with terms such as fetal alcohol effects (FAE), prenatal alcohol exposure (PAE), and prenatal exposure to alcohol (PEA). Recently, the Institute of Medicine (Stratton et al., 1996) proposed two additional terms. The first, “alcohol-related birth defects” (ARBD), applies to individuals with evidence of only physical anomalies such

as cardiac, skeletal, renal, ocular, and auditory malformations or dysplasias. The second term, “alcohol-related neurodevelopmental disorder” (ARND), is indicated when there is evidence of CNS abnormalities such as microcephaly and micrencephaly, structural brain abnormalities, and neurological hard or soft signs. In an effort to unify these numerous and varied labels, Barr and Streissguth (2001) introduced the term “fetal alcohol spectrum disorder” (FASD), which currently is the accepted term in Canada.

Throughout this dissertation, the term FAS will be used to denote only those individuals who, according to the researchers, have met full criteria for FAS. Similarly, the term FAE will be used when referring to alcohol-exposed individuals who have not met full FAS criteria, regardless of the diagnostic terminology of the authors whose research is presented herein. Lastly, the term FASD will be used when referring collectively to children with FAS or FAE.

Determinants of Outcome

Numerous alcohol-related, biological, and environmental variables interact to determine how prenatal alcohol exposure affects a given individual. Stratton et al. (1996) presented a multifactorial model that captures the essence of this complexity. A child’s outcome is affected foremost by the parameters of alcohol consumption, including quantity, frequency, and drinking pattern, along with when during the pregnancy drinking occurred. Research in this area broadly suggests a dose-dependent relationship between the amount of alcohol ingested and adverse fetal effects. Moderating this relationship, however, is the pattern of intake. Binge drinking appears much more harmful to the fetus relative to continuous drinking, likely because of spikes in blood alcohol concentration

(Maier & West, 2001). Moreover, although the brain is susceptible to alcohol-induced brain damage throughout gestation, there are critical periods of heightened vulnerability. Many of these critical periods are situated within the first two months of gestation. Regrettably, many women at this stage do not realize they are pregnant and may engage in bingelike social drinking (the “weekend binge”; Maier & West, 2001). For example, in the Seattle Longitudinal Prospective Study on Alcohol and Pregnancy, Streissguth, Barr, and Sampson (1990) found that maternal binge drinking in the month before women realized they were pregnant was the best predictor of deficits in attention, memory, cognitive processing, and problem-solving flexibility. Moreover, children exposed prenatally to bingelike maternal drinking were more likely to be rated as having learning problems, academic delays, and difficulties with hyperactivity and impulsivity.

Biological variables are also thought to influence the expression of prenatal alcohol exposure. One such variable is the mother’s ability to metabolize alcohol. Alcohol is metabolized primarily in the liver, where it is broken down into acetaldehyde and acetate by the enzyme alcohol dehydrogenase. There are known variations in the gene that gives rise to this enzyme, resulting in different capacities to metabolize alcohol. Recent studies have shown that variants of the alcohol dehydrogenase gene may afford an exposed fetus some protection against alcohol (Stoler, Ryan, & Holmes, 2002; Viljoen et al., 2001). Methodological differences, however, have led to some disagreement as to which genetic variant confers the most protection. Other biological variables relate to the age of the pregnant mother and how many previous children she has had. It appears that

alcohol's harmful effects are more pronounced in mothers over the age of 30 and in those who have had previous children with FAS (Jacobson, Jacobson, & Sokol, 1996).

Environmental variables are also thought to influence the expression of prenatal alcohol exposure. Among these, low socioeconomic status (SES) and nutritional deficiencies (Abel & Hannigan, 1995) figure prominently. Low SES, in particular, may be a key variable in that it engenders other risk factors such as drug abuse, poor nutrition, poor general health, limited obstetric care, and increased stress (Abel & Hannigan, 1995; Stratton et al., 1996). These factors, although external to the mother and her unborn child, lead to adverse internal biological conditions by provoking cellular, endocrine, and other biochemical changes that enhance alcohol's toxic action.

In summary, there are numerous and varied factors, both internal and external to the mother and child, that determine how prenatal alcohol exposure is expressed. This section focussed on the most important variables that affect a developing fetus to the point of birth. It is also noteworthy that environmental variables continue to exert a critical influence on the child's outcome throughout infancy and beyond. Socioeconomic status, nutrition, pediatric care, social supports, and early diagnosis and intervention serve as ongoing protective or harmful influences (Stratton et al., 1996).

Sequelae of Prenatal Alcohol Exposure

The effects of prenatal alcohol exposure are far-reaching. This section summarizes recent research within each major domain of functioning.

Somatic Findings

Pre- and postnatal growth deficiency and a distinctive pattern of craniofacial features are two of the hallmarks of FAS, according to the criteria set forth by Jones and Smith (1973). Growth deficiency is indicated when an infant's weight and/or height are below the 10th percentile (Stratton et al., 1996). There is some evidence to suggest, however, that growth reduction is the poorest predictor of fetal alcohol exposure relative to the other two features of the classic FAS triad. An infant's growth may be affected mildly with drinking in early pregnancy and more severely with drinking in late pregnancy; however, women who stop drinking by mid gestation tend to have infants of normal weight (Clarren, 2005).

The discriminating craniofacial features include a short palpebral fissures, flat midface, short nose, indistinct philtrum, thin upper lip, and microcephaly. Associated facial features include epicanthal folds, low nasal bridge, minor ear anomalies, and micrognathia (Stratton et al., 1996). Other somatic manifestations include cardiac, skeletal, renal, and dental abnormalities, visual problems, and hearing deficiencies (Church, Eldis, Blakley, & Bawle, 1997; Streissguth, Clarren, & Jones, 1985).

Neuropsychological and Psychological Deficits

Cognitive Ability

FAS is almost always associated with compromised intellectual ability. As noted earlier, FAS is considered the leading cause of mental retardation in the Western world (Stratton et al., 1996); however, the range of intellectual impairment is extremely broad. A review by Mattson and Riley (1998) indicated that the mean intelligence quotient (IQ)

of a child with FAS is around 70, with a range of 20 to 120. There is no conclusive evidence that verbal IQ and performance IQ are affected differentially, and research suggests that IQ is relatively stable over time.

Those with FAE typically have intellectual impairments as well, although groupwise, they may not be as severely affected as those with FAS. For example, in a sample of 61 adolescents, Streissguth et al. (1991) found that those with the FAS had a mean IQ of 66, whereas those with FAE had a mean IQ of 73. Similarly, in a smaller sample of 20 children with either FAS or FAE, Conry (1990) found that those with FAS had a mean full scale IQ (FSIQ) of 60.1, compared to 86.0 for those with FAE.

Attention

Inattention and hyperactivity are almost synonymous with FASD. Numerous studies have documented attention deficits (Kerns, Don, Mateer, & Streissguth, 1997; Mattson, Calarco, & Lang, 2006; Nanson & Hiscock, 1990; Streissguth et al., 1984; Streissguth, Bookstein, Sampson, & Barr, 1995), and attention deficit/hyperactivity disorder (ADHD) is often diagnosed comorbidly with FASD (Coles, 2001). In an attempt to characterize the attentional deficits characteristic of FASD, a recent study by Mattson and colleagues (2006) investigated how well 20 children with FASD could engage, disengage, and shift their attention. They used a computerized attention test with three conditions: visual focus; auditory focus; and auditory-visual shifting. In the visual condition, children pressed a button when a yellow square appeared on a computer monitor. In the auditory condition, children pressed a button for low-sounding tones. In the visual-auditory shift condition, children responded alternately to yellow square and

low tones. That is, successfully detecting either a visual or an auditory stimulus required disengaging their attention and responding to stimuli in the opposite modality. In all three conditions, stimuli were presented with an interstimulus interval (ISI) that ranged from 450 milliseconds to 30 seconds. In the visual and auditory conditions, children with FASD were significantly less accurate than control children. With respect to reaction time, children with FASD were slower to respond to visual stimuli at all ISIs; however, they were slower to respond to auditory stimuli only when the ISI was more than 10 seconds. On the shifting condition, children with FASD were as accurate as control children, but they were significantly slower to respond. Based on these findings, Mattson and colleagues (2006) concluded that visual focussed attention was consistently impaired in FASD, whereas auditory attention was impaired only at longer target intervals.

At least two studies have not found attentional impairments in children with FAS. Boyd, Ernhart, Greene, Sokol, and Martier (1991) found in a large sample of preschoolers that prenatal alcohol exposure did not affect performance on a measure of sustained attention. Similarly, in a large sample of 6-year-old children, Fried, Watkinson, and Gray (1992) did not find a relationship between prenatal alcohol exposure and measures of attention. Indeed, these authors found that mild alcohol exposure was associated with less impulsive responding on a measure of inhibition, along with lower maternal ratings of impulsive behaviour. Nevertheless, the results of these two studies appear to be at odds with the numerous other studies that have documented attentional deficits in children with FASD.

Executive Functioning

Executive functions are higher order cognitive processes that are important for effective and situation-appropriate behaviour. Although there is no single agreed-upon definition of executive functions, they are thought to comprise cognitive processes such as initiation, inhibition, working memory, set shifting, planning, decision-making, judgement, abstract reasoning, problem-solving, and self-perception (Tranel, Anderson, & Benton, 1994; Stuss & Benson, 1986; Zelazo & Müller, 2002). Although executive functions are contrasted with more basic cognitive processes such as motor activity, sensation, perception, attention, or memory, they are thought to involve an integration of these basic processes and thus depend on their development (Connor, Sampson, Bookstein, Barr, and Streissguth, 2000).

A number of studies have found executive functioning impairments in children with prenatal alcohol exposure. Kodituwakku, Handmaker, Cutler, Weathersby, and Handmaker (1995) administered a number of executive functioning tasks to 10 children and adolescents with FAS or FAE, and 10 controls. Children in the FASD groups were relatively high-functioning as indicated by equivalent performance to controls on a measure of receptive vocabulary. Nevertheless, Kodituwakku and colleagues found that children with FASD performed more poorly than controls on the Wisconsin Card Sorting Test (WCST), verbal fluency, and the Progressive Planning Test, which is similar to the Tower of London.

Several studies have found impairments on the WCST, which is thought to measure problem solving, set shifting, and using feedback to guide behaviour. In an

exploratory study of nine alcohol-exposed adolescents and 174 controls, Olson, Feldman, and Streissguth (1998) found that those with prenatal alcohol exposure obtained fewer categories on the WCST, made more errors, and made more non-rule-based “other” responses, suggestive of disorganized, unplanned responding. The alcohol-exposed adolescents also performed below controls on digit span and on the Seashore Rhythm test. Another study by Kodituwakku and colleagues found in a sample of 20 children and young adults with FAS or FAE, and 20 control children matched by age, gender, and ethnicity, that those with prenatal alcohol exposure obtained significantly fewer categories on the WCST and made more perseverative errors (Kodituwakku, May, Clericuzio, & Weers, 2001). Alcohol-exposed participants also performed worse on the Children’s Executive Functioning Scale, a behavioral measure of social appropriateness, inhibition, problem solving, initiative, and motor planning. The WCST accounted for a large proportion of the variance on this measure.

Mattson, Goodman, Caine, Delis, and Riley (1999) investigated executive functioning in a sample of 18 children with FAS or FAE, and 10 nonexposed control children. These researchers used subtests from the Delis-Kaplan Executive Function Scale (D-KEFS) that measured cognitive flexibility, inhibition, planning, concept formation, and abstract verbal reasoning. Children in the alcohol-exposed group performed worse than control children on all measures. Further, the two subgroups of alcohol exposed children (FAS and FAE) displayed equivalent performance, underscoring the point that cognitive impairments can occur in prenatal alcohol exposure even in the absence of facial dysmorphology.

Using two subtests from the D-KEFS, Schonfeld, Mattson, Lang, Delis, and Riley (2001) investigated verbal and nonverbal fluency in 10 children with FAS and 8 children with FAE, aged 8 to 15 years. Relative to control children, those with FAE displayed deficits in both fluency tasks, but the two subgroups (FAS and FAE) did not differ significantly from each other. Moreover, group differences persisted even after controlling for intelligence.

In a recent study, Burden, Jacobson, Sokol, and Jacobson (2005) investigated attention and working memory in a sample of 337 African-American children, aged 7.5 years, who were exposed prenatally to alcohol at moderate to heavy levels. They selected neuropsychological measures on the basis of their relation to four dimensions of attentional function identified by Mirsky and colleagues (1991): sustained attention, focussed attention, shift, and encode. Sustained attention was measured with two visual forms of a continuous performance test (CPT), and focused attention with Digit Cancellation. Shifting was measured with the WCST, Category fluency, and Tower of London. Encoding, analogous to working memory, was measured with Digit Span and Arithmetic from the WISC-III, Corsi blocks, and the Seashore Rhythm test. Among the four dimensions of attention, prenatal alcohol exposure was associated primarily with poor working memory, particularly when information had to be manipulated rather than simply maintained in working memory (Burden et al., 2005). This deficit was most pronounced in children who were born to mothers 30 years and older, and persisted even after controlling for intelligence. Surprisingly, these authors did not find a relation between prenatal alcohol exposure and sustained attention, focussed attention, or shifting.

Although most studies investigating executive functioning in FASD have used school-aged children, one recent study investigated executive functioning in preschool children. Noland and colleagues (2003) recruited a sample of 316 four-year olds who were prenatally exposed to alcohol, cocaine, or marijuana. Children completed a tapping inhibition task, a category fluency task, and a motor fluency task. The authors found a significant negative relation between alcohol exposure and performance on the inhibition tapping task, even after controlling for verbal intelligence, prenatal drug exposure, and postnatal environmental factors including maternal intellectual and psychosocial functioning, current drug or alcohol use, and home environment. Alcohol-exposed children did not differ significantly on the category fluency or motor fluency tasks. In addition, cocaine and marijuana were not related to any of the measures. On the other hand, the authors commented that less than 30% of the sample mastered the rules of the inhibition tapping task, making it unclear whether children demonstrated weak inhibition or weak rule learning.

Executive functioning has also been investigated in adult FASD samples. Kerns et al. (1997) divided a group of 16 alcohol-exposed young adults into two groups of eight participants, those with average-range IQs (90+) and those with below-average IQs (< 90). They found that both groups performed poorly on measures of verbal fluency, but only the low-IQ group showed impaired nonverbal fluency.

Connor et al. (2000) investigated whether prenatal alcohol exposure affects executive functioning directly, or whether observed executive impairments are mediated through decrements in intelligence. The participants were 30 men diagnosed with FAS

or FAE, 15 control individuals, and data from the Seattle Longitudinal Prospective Study. All participants completed a large battery of executive functioning tasks along with the Wechsler Adult Intelligence Scale - Revised Edition. The authors found that select scores from the Stroop, Trails, WCST, Ruff Figural Fluency, and Auditory Consonant Trigrams were directly affected by prenatal alcohol exposure. In contrast, performance decrements on word fluency, cognitive estimation, digit span, and the California Verbal Learning Test (CVLT) appeared to be mediated by decrements in intelligence. Connor and colleagues suggested that the tests in the former group might be particularly useful in the neuropsychological evaluation of individuals with FASD.

It should be noted that although most studies have documented executive impairments in FASD, a few studies have not. In Kodituwakku et al.'s (1995) study, children in the FASD groups performed equivalently to controls on two measures of working memory (delayed response tests and the Self-Ordered Pointing Test), and on a measure of inhibition. Similarly, Kerns et al. (1997) found that alcohol-exposed children with average-range IQs performed within the average range on nonverbal fluency, although the number of design repetitions was somewhat elevated. And in Burden et al.'s (2005) study, prenatal alcohol exposure was not associated with poorer WCST performance.

In summary, with few exceptions, children with FASD have been shown to have difficulty within most areas of executive functioning. In addition, most studies have documented that executive impairments are of a degree beyond what would be predicted based on compromised general intelligence.

Learning and Memory

Impairments in learning and memory have also been documented in those with prenatal alcohol exposure. Mattson, Riley, Delis, Stern, and Jones (1996) found on the California Verbal Learning Test - Children's Edition (CVLT-C) that children with FAS recalled fewer words than controls across all learning and recall trials; however, they retained a similar proportion of words over at 20-minute delay. This finding, in combination with poorer recognition than controls, indicates weak encoding but intact retention. A follow-up study by Mattson et al. (1998) found an identical pattern of impaired verbal learning but intact retention in children with FASD. Kerns and colleagues (1997) similarly found that alcohol-exposed individuals with below-average IQs had substantial difficulty on all facets of the CVLT, including retention and recognition. Higher-functioning individuals, however, demonstrated a pattern similar to the studies by Mattson and colleagues, with poorer learning, intact retention, and poorer recognition. Collectively, these results suggest that individuals with FAS are likely to have difficulty learning new verbal information, but what they manage to learn, they are likely to remember. This pattern, however, may be moderated by intelligence.

Fewer studies have examined learning and memory of nonverbal information. Uecker and Nadel (1996) employed the Memory for 16 Objects task (Smith & Milner, 1981) with a group of 15 children with FAS. In this task, participants were asked to name 16 toy objects arranged in various locations on a sheet of paper. Immediately following this, they were tested on object recall, object recognition, and recall of object location, as assessed by how the array was reconstructed. Uecker and Nadel found that

children with FAS had intact immediate but poor delayed object recall. They also evidenced spatial memory deficits and significantly distorted the array. A follow-up study by the same authors found impaired spatial memory impairment in absence of an object memory impairment (Uecker & Nadel, 1998). In other words, the children displayed poor memory for object location, but not for the objects themselves. Kaemingk and Halverson (2000) also observed spatial memory deficits in children with FAS; however, these findings did not persist after controlling for visual perceptual skills and verbal memory abilities. In consequence, they argued that children with FAS do not have a material-specific memory deficit for spatial information.

Mattson and Roebuck (2002) assessed both verbal and nonverbal learning in a sample of 35 children and adolescents with FAS or FAE. They compared these abilities to those of 35 control participants matched for age, gender, ethnicity, and SES. Their measures included the CVLT-C, subtests from the Wide Range Assessment of Memory and Learning (WRAML), and the Biber Figure Learning Test. They found that alcohol-exposed individuals learned less information than controls on all tests. Similar to findings reported earlier, long-term retention of verbal information was commensurate with initial acquisition. However, this pattern did not hold true for nonverbal information: the alcohol-exposed participants demonstrated a selective deficit in the long-term retention of nonverbal information.

To summarize, the bulk of research findings suggest that FAS is associated with deficient acquisition of verbal information, but adequate retention. The acquisition of

nonverbal information appears similarly affected; however, the results are equivocal regarding whether there is a specific deficit in retaining nonverbal information.

Visuospatial Abilities

Visuospatial abilities in individuals with FASD have not been investigated as intensively as have other neuropsychological domains. The results of the few studies in this area, however, suggest that visuospatial abilities, particularly visual-motor integration, may be a consistent area of difficulty. Several studies have found impaired performance on the Beery Developmental Test of Visual-Motor Integration (Beery VMI), a measure that requires children to copy geometric shapes of increasing complexity (Janzen, Nanson, & Block, 1995; Mattson et al., 1998; Uecker & Nadel, 1996). Janzen and colleagues found that the impairments in visual-motor integration occurred in the context of adequate visual-perceptual matching, as measured by The VMI Developmental Test of Visual Perception.

It is important to note that the Beery VMI is not a pure measure of visuospatial processing because it requires complex motor responding. This is an area of difficulty for individuals with FASD (see below). Kaemingk and Halverson (2000) addressed this issue by administering two matching-to-sample tasks: Judgement of Line Orientation; and Facial Recognition. They found that children with FASD performed significantly worse than did controls on the line orientation task, but not on facial recognition. Interestingly, they observed that all participants performed within age-appropriate levels on facial recognition. They speculated that facial recognition might be an area of

preserved functioning in FAS. Similar findings of intact facial recognition by other investigators suggests this may indeed be the case (Uecker & Nadel, 1996).

Motor Functioning

The results of numerous studies document impairments in motor functioning. A review by Mattson and Riley (1998) detailed consistent findings in delayed motor development, impaired fine- and gross-motor skills, and deficits in motor speed, strength, and dexterity. Research in this area is bolstered by animal models, which have found gait disturbances, abnormal reflexes, and poor balance (Mattson & Riley, 1998).

Academic Achievement

Academic achievement is typically poor in alcohol-exposed children. Research from the Seattle Longitudinal Prospective Study on Alcohol and Pregnancy found in a sample of 500 children deficits in Arithmetic and Spelling as measured by the Wide Range Achievement Test - Revised Edition (Streissguth, Barr, Sampson, & Bookstein, 1994). Mathematics appears particularly susceptible to prenatal alcohol exposure. Kopera-Frye, Dehaene, and Streissguth (1996) found in 29 individuals with FAS or FAE poor performance on calculation abilities in the context of adequate number reading and writing ability. Similarly, children with FASD have been shown to perform poorly on the Arithmetic subtest from the Wechsler scales (Streissguth, Barr, Olson, & Sampson, 1994), although this test is thought to rely heavily on working memory along with arithmetic abilities.

Behavioural, Psychosocial and Adaptive Functioning

Studies in this area have typically found that children with FASD exhibit poor judgement, are less able to learn from mistakes, and are hyperactive and impulsive. They are at high risk for engaging in disruptive behaviours, aggression, and delinquency, and for getting into trouble with the law. They are described as not considering the consequences of their actions, lacking initiative, and unresponsive to social cues. Social skills and relations are often delayed (Mattson & Riley, 2000; Roebuck, Mattson, & Riley, 1999; Stratton et al., 1996; Streissguth et al., 1991). In addition, there is mounting evidence that individuals with FASD have a high probability of developing psychiatric illnesses later in life. The most prevalent disorders appear to be depression, bipolar disorder, psychotic disorders, personality disorders, and drug and alcohol abuse (Baer, Sampson, Barr, Connor, & Streissguth, 2003; Famy, Streissguth, & Unis, 1998; O'Connor et al., 2002).

Individuals with FASD also have been found to have poor adaptive functioning and are less likely to live independently. For example, in a longitudinal study by Streissguth and colleagues in which 473 individuals with FASD were followed over time, 80% required dependent living (Streissguth, Barr, Kogan, & Bookstein, 1997). An interesting finding in this study was that dependent living was required even in relatively high-functioning individuals. In fact, only 16% of participants met criteria for mental retardation. The surprisingly small protective influence that higher intelligence confers in FASD has also been found for other such “secondary disabilities” (Streissguth et al., 1997; Streissguth et al., 1991; Thomas, Kelly, Mattson, & Riley, 1998). Secondary

disabilities are those that occur over time from a mismatch between the primary disabilities in FASD (i.e., functional difficulties resulting from CNS damage due to prenatal alcohol exposure) and environmental expectations. They include such things as mental health problems, psychiatric illness, disrupted school experience, trouble with the law, incarceration, inappropriate sexual behaviour, and so on. Presumably, secondary disabilities can be mitigated with appropriate interventions and support (Streissguth et al., 1997).

To summarize the results of this section, perhaps Mattson et al. (2001) captured best the neuropsychological findings associated with FASD by concluding that “in general, alcohol-exposed children both with and without FAS show significant impairment in all neuropsychological areas with few qualitative differences observed between the FAS and PEA/FAE groups.”

Transfer of Learning in Children with FASD

Along with the neuropsychological findings detailed above, there are numerous anecdotal accounts that children with FASD have particular difficulties generalizing information from one context to another. Parents who attend FASD support groups frequently share experiences describing how their child with normal-range intelligence is able to learn and remember information in one situation, but unable to transfer that learning to seemingly similar situations (Coggins, Friet, & Morgan, 1998; Streissguth, 1997). For example, when a child with FASD is cautioned not to play on the street, he or

she may interpret this literally (“I shouldn’t play on *my* street”) and not understand that this caution refers to *all* streets. Some parents have observed that their child is able to learn and remember simple arithmetic word problems (*Jane has 2 apples, and picks 2 more. How many apples does she have all together?*), but reportedly cannot answer similar questions with different details (*John has 2 books, and buys 2 more. How many books does he have all together?*).

An Overview of Transfer of Learning

Definition and Importance of Transfer of Learning

Transfer of learning (also known simply as “transfer”) refers to how “previous learning influences current and future learning, and how past or current learning is applied or adapted to similar or novel situations” (Haskell, 2001). It is fundamental to much of human cognition and intelligence, and is regarded as the primary goal of the educational system. As a way of thinking, perceiving, and processing information, transfer is fundamental to all learning (Carragher & Schliemann, 2002; Haskell, 2001). It forms the basis for the simplest and the most complex of ideas. Simple transfer is demonstrated anytime we use phrases such as *it’s like*, *it’s akin to*, *by the same token*, *it resembles*, or *it’s analogous to* (Haskell, 2001). Transfer allows us to use a rock as a hammer when driving in a tent stake, or a dime as a screwdriver to repair the wheels of a suitcase in the middle of the airport.

We live in a world of flux, and are faced continuously with a staggering volume of information impinging on our senses. If everything were different from everything

else, we would be unable to function. Thus, transfer of learning is essential for survival because it reduces our world to manageable proportions and makes the world familiar (Haskell, 2001). It allows us to organize the world into familiar categories, in turn allowing us to organize, adapt, and monitor our behaviour in situations that ostensibly seem different but, on closer inspection, share recognizable commonalities. In short, we bring our learning, knowledge, and experience to bear on the situation at hand, thereby minimizing novelty (Shafto & Coley, 2003).

Historical Overview of Transfer Research

Before the turn of last century, transfer of learning was known as the study of *formal discipline* (Mayer, 2004). It was predicated on the idea that the specific content of learning did not matter. As long as one could master any kind of knowledge, the mind would be strengthened enough to learn and apply information in novel contexts. This view was highly influential in guiding the American and British educational systems. Students were taught classics, geometry, Latin, and chess in the belief that this would enhance general thinking skills and result in transfer of learning beyond the classroom (Barnett & Ceci, 2002). Binet adhered to this approach, and believed in “mental orthopaedics” involving exercises of will, attention, and discipline.

Edward Thorndike and Robert Woodworth (Thorndike, 1913, as cited in Carraher & Schliemann, 2002; Thorndike & Woodworth, 1901) initiated the first experimental investigations of transfer of learning. They did not find evidence of generalized transfer according to formal discipline tenets. Thus, they posited an empiricist stance in which learning occurs passively through the recognition of similarities between situations.

They termed these similarities “identical elements,” and described them as physical, objective features that different situations have in common. Thorndike and Woodworth (1901) went so far as to claim that transfer of learning *rarely* occurs unless identical elements were present in both contexts.

Some of Thorndike’s contemporaries adopted a contrasting view. Charles Judd de-emphasized surface physical commonalities (i.e., identical elements) and focussed instead on conceptual similarities among situations. In his classic experiment, two groups of boys practised throwing darts at underwater targets. Beforehand, boys in the experimental group received instruction on the general principle of light refraction, and how this phenomenon could affect their performance. Boys in the control group did not receive such instruction. Judd found that boys who received the refraction lesson were more accurate at throwing darts at new target locations of various depths (Judd, 1908). On the basis of these findings, Judd suggested that transfer occurs not only on the basis of identical elements between two situations, but also via the transfer of abstract general principles.

In the 1940s, proponents of Gestalt psychology built upon Judd’s work, claiming that transfer was enhanced by developing an understanding of the structural features of a task (Carragher & Schliemann, 2002). For example, in a classic study by Wertheimer, students learned how to calculate the area of a parallelogram with parallel sides along the horizontal, then were asked to calculate the area of a parallelogram with parallel sides along the vertical. Participants who received instructions emphasizing the structural features of the problem were more successful in calculating the area of the second

parallelogram, presumably because they were able to transfer the deeper principle (Wertheimer, 1961, as cited in Carraher & Schliemann, 2002). Both Judd's and Wertheimer's experiments were influential in demonstrating that the transfer and generalization of learning occurs best when general principles are applied specifically to novel contexts that require the same principles.

Transfer research began to flourish in the 1970s and 1980s as researchers created puzzle-like problems that could be solved by applying a set of rules. Typically, participants first learned about or solved some problem, then were presented with an analogous, experimental problem that could be solved presumably by applying the same logic or procedures as the first problem. Most researchers found that transfer to the experimental task did not occur unless participants were cued (Carraher & Schliemann, 2002). Gick & Holyoak (1980) conducted a famous study demonstrating this. They presented participants with a problem involving a doctor who had to remove an inoperable stomach tumour using a sufficiently large amount of radiation. Participants were asked how this could be accomplished without damaging the surrounding tissue. The solution was to direct multiple converging beams to the tumour, which collectively would destroy it. Prior to this, some participants read a story involving a general who had to capture a fortress located in the centre of a country using a large number of soldiers; however, due to the presence of land mines, the entire army could not be directed to the fortress en masse. The general accomplished this by sending a small number of men down a number of inroads that converged upon the fortress. Gick and Holyoak found that only 10% of participants successfully solved the tumour problem

without first reading the army story, compared to 30% of those who did read the army story. When provided with a hint to think about the army story, however, approximately 75% of participants successfully figured out how to destroy the tumour.

Since then, transfer of learning has come to the attention of cognitive psychologists, who have focussed primarily on the underlying mechanisms of transfer and have created sophisticated information-processing models to explain the acquisition, processing, and retention of information (Haskell, 2001), the differential efficacy of certain kinds of cues, and surface- versus deep-structural differences (Barnett & Ceci, 2002). Further, research on the phenomenon has proceeded under numerous guises. Transfer of learning forms the basis of analogical transfer, generalization, mental abstraction, generic thinking, inductive reasoning, isomorphic relations, metaphor, and mental models (Haskell, 2001).

Of these, analogical transfer has received the most research attention. Analogical transfer refers to the transfer of previously acquired knowledge or solutions from one context to another (Chen, 2002). More technically, it refers to the process wherein some learned (base) model serves as an analogue to solve novel (target) problems of a similar kind (Reeves & Weisberg, 1994). For example, a child trying to figure out a math problem may flip through his class notes until he finds a problem with a similar structure, then apply that knowledge to the problem at hand. Many authors have concluded that analogical reasoning is central to learning, thinking, and reasoning (Halford, 1992).

Levels and Kinds of Transfer

Over the years, many researchers have tried to impose order on the vast and amorphous transfer literature. For example, Mayer (2004) identified three major views of transfer: general transfer; specific transfer; and specific transfer of general knowledge. In essence, these views refer largely and rather simplistically to the study of formal discipline, Thorndike's identical elements model, and Judd's general principles model, respectively.

Recently, Haskell (2001) presented a comprehensive and elegant six-level taxonomy of transfer that captures the complexity of and organizes current research in this area. These levels are summarized in Table 1. Level 1 is *nonspecific transfer*, and refers to the notion that all learning depends on connectivity to past learning; therefore, all learning is, fundamentally, transfer of learning. Level 2 is *application transfer*, and refers to the application of learning in a specific situation. For example, after learning about how to change a tire, actually changing it would involve application transfer. Level 3 is *context transfer*, and occurs when one transfers knowledge gained in one situation to a *slightly* different situation. This would be exemplified by changing a tire in one's driveway versus changing it at the side of the road. Level 4 is *near transfer*. This occurs when knowledge gained in one situation is transferred to novel situations that are similar but not identical to the original context. For example, learning how to change a tire on a car may transfer to learning how to change a tire on a bicycle. Level 5 is *far transfer*, and occurs when knowledge is applied to situations that are quite dissimilar to the original learning context. Benjamin Franklin's perceiving lightning as a "big spark" is

an example of far transfer (Haskell, 2001). Similarly, Gick and Holyoak's (1980) analogical reasoning study, involving the fortress capture and tumour removal, involve this level of transfer. Finally, level 6 transfer is *displacement or creative transfer*. This higher order transfer is proposed to undergird the creation of new concepts and form the basis of creativity. Haskell proposed that the first three levels of transfer really are not transfer proper; instead, they involve simple learning (levels 1 and 2) and the application of learning (level 3). Levels 4 through 6 represent increasingly distant or higher order levels of transfer. In addition to these six *levels* of transfer, Haskell identified 14 *kinds* of transfer, summarized in table 2 along with examples.

Interestingly, several prominent transfer researchers paint a bleak picture of transfer of learning with respect to research findings and practical applications. Detterman (1993) lamented that “if there is a general conclusion to be drawn from the research on transfer, it is that the lack of general transfer is pervasive and surprisingly consistent.” McKeough, Lupart, and Marini (1995) observed that achieving transfer is one of “teaching’s most formidable problems”, and that researchers “have been more

Table 1. Levels of transfer (Haskell, 2001).

Level	Description
1 - Nonspecific	All learning involves transfer to some degree
2 - Application	Applying knowledge to a specific situation
3 - Context	Applying knowledge to a slightly different situation
4 - Near	Applying knowledge to somewhat different situations
5 - Far	Applying knowledge to very different situations
6 - Displacement / Creative	Using knowledge to create new ideas

successful in showing how people fail to transfer learning than they have been in producing it.” And Gentner, Loewenstein, and Thompson (2003) noted that “our ability to take advantage of our prior experiences is highly limited.” The reasons for transfer failure are manifold. At the research level, there is little agreement on the fundamentals of transfer, including what it is, the extent to which it occurs, and its underlying mechanisms (Barnett & Ceci, 2002). Haskell’s framework, summarized in tables 1 and 2, emphasizes the complex and multifaceted nature of transfer; thus, different researchers undertaking studies of the phenomenon may not be researching the same construct with appropriate methodologies (Chen, 2002). For example, in a typical transfer task, participants are assumed to draw upon the knowledge gained from a learning situation and apply it to an analogous situation. This kind of design cannot demonstrate conclusively that participants did not benefit from the training task; it concludes only that participants did not reach a particular end state (Carragher & Schliemann, 2002). In everyday life, these same authors identified countless examples of transfer failure in schools, universities, businesses, and the military. For example, Detterman (1993) noted that, as a university instructor, he does not “count on transfer”, nor does he “try to promote it except by explicitly pointing out where taught skills may be applied.”

Factors Affecting Transfer

Successful transfer of learning depends on many variables. Given the pervasiveness and importance of transfer of learning in everyday life, this is easy to understand. One variable is knowledge base, which many researchers view as paramount to successful

transfer, and which likely encompasses several derivative variables that also affect transfer (Coley, Hayes, Lawson, & Moloney, 2004; Howard, 2000). Galotti (1989) noted

Table 2. Kinds of transfer (Haskell, 2001).

Kind of Transfer	Description	Example
Content-to-Content	Applying knowledge learned in one area to another area	Knowledge of brain-behaviour relationships informs cognitive rehabilitation
Procedural-to-Procedural	Applying skills learned in one area to another area	Learning how to administer the WISC facilitates administering the WAIS
Declarative-to-Procedural	When learning about something helps actually doing something	Learning about cognitive rehabilitation facilitates practising it
Procedural-to-Declarative	When practical experience in an area enhances knowledge of that area.	Practising cognitive rehabilitation informs brain-behaviour relationships
Strategic	When meta-knowledge gained through self-monitoring facilitates future problem solving	Knowing how one learns and remembers best improves future problem solving
Conditional	Knowledge about <i>when</i> to apply knowledge learned in one context to another context	Knowledge that adults with mental retardation may reason more like children
Theoretical	Knowledge of deeper relationships in one area that transfer to another area	Knowing that rust is simply slow combustion
General / Nonspecific	When general knowledge transfers to a current situation	Similar to the notion of formal discipline
Literal	Applying declarative or procedural knowledge directly to new learning	Using knowledge and skills gained through assessing children to assessing adults
Vertical	Applying more basic or fundamental concepts to the learning of higher order concepts	Developing a solid foundation in mathematics to learn more complex operations
Lateral	Applying learning at one hierarchy level to an equivalent level	Learning how to administer the WISC facilitates administering the WAIS
Reverse	When existing knowledge is modified from the addition of new information	Using research on executive functioning to counter the idea that the frontal lobes are “silent”
Proportional	When knowledge gained in one context is transferred to a situation differing in magnitude or scope	Recognizing a melody played in a different octave (Haskell, 2001)
Relational	Analogical transfer, in which knowledge is transferred to situations that share a similar structure.	Understanding that the treatment for various anxiety disorders fundamentally involve exposure to the feared stimulus

that “good everyday reasoning” is strongly related to the breadth and depth of one’s knowledge base. This is because the broader one’s knowledge base, the greater the capacity to link pieces of information and isolated strategies that can then be recombined into novel forms (Coley et al., 2004). Knowledge alone, however, is not enough; equally important is knowledge organization. A jumbled mass of information may not be understood deeply enough to allow its critical application (Haskell, 2001).

Related closely to knowledge base is level of expertise. In part, expertise reflects possession of a broad knowledge base relative to novices (Galotti, 1989; Glaser, 1984). For example, Glaser (1984) noted that problem solving difficulties in novices stem from an inadequate knowledge base rather than from weak processing capabilities or inadequate problem solving heuristics. Additionally, expertise in a given domain alters the way in which knowledge is organized (Coley et al., 2004).

The degree of similarity between situations is an important mediator of transfer. Two main kinds of similarity are recognized in the transfer literature, *surface* and *structural*. Surface features are superficial, solution-irrelevant details such as names or characters in a story. Structural features refer to causal relations among elements, or to the solution principles that the source and target problems have in common (Catrambone, 2002; Chen, 2002; Coley & Shafto, 2003). Bassok (2002) noted that solution-irrelevant surface similarities are usually more salient than solution-relevant structural similarities. A student given a pulley problem in physics, for example, may try to solve the problem by referring to other pulley problems, when in fact the two pulley problems may not rely on the same physics principle (Novick, 1988). By the same token, people may not

recognize that problems differing in surface features actually have a similar structure. This was demonstrated in Gick and Holyoak's (1980) study where most participants missed the relevance of the army general story in solving the tumour problem unless they were cued. The presence or absence of cueing is referred to as *spontaneous transfer* versus *informed transfer* (Bassok, 2002). A number of studies have demonstrated that expertise in a domain facilitates the perception of structural versus surface features of a problem (Novick, 1988). Individuals skilled at transfer are able to see beyond superficial appearances, understand deeper, fundamental principles, and recognize important commonalities. In domain novices and in people less able to generalize information, knowledge is tied more tightly to the original context in which it was learned (Coley & Shafto, 2003; Goldstone & Sakamoto, 2002). Further, these individuals are more susceptible to distraction or being "misled" by surface features, thereby arriving at erroneous solutions (as in the pulley problem).

Another line of research suggests that familiarity with the new or target situation facilitates transfer. For example, Luria (1977, as cited in Goswami, 2002) found that peasants had difficulty making logical deductions about snow, with which they were unfamiliar, yet performed well on structurally similar problems involving cotton, with which they were familiar. Goswami (2002) reviewed research demonstrating that children, too, are capable of analogical reasoning based on *structural* similarity when reasoning in familiar domains. For example, using a series of picture cards depicting analogies in the form of *a is to b, as c is to d*, Goswami and Brown (1989) found that preschoolers could successfully complete analogical reasoning tasks when faced with

familiar concepts such as breaking, cutting, and melting. These authors suggested further that children's capacity for analogical reasoning increases with age largely as a function of knowledge about relevant relations, a view similar to that of Coley et al. (2004) and Galotti (1989). This view, along with other related research, opposes early Piagetian views that children cannot understand structural similarity until they reach the formal operations stage of development in adolescence (Smith, 2002). Piaget's tasks, however, often involved uncommon relations, such as "steering mechanisms," with which most children would have been unfamiliar (Richland, Morrison, & Holyoak, 2006). The research by Goswami and colleagues also contrasts earlier analogical transfer research that suggested children are "perceptually bound" and rely on surface similarities to solve problems (Goswami, 2002).

Lastly, level of processing also affects transfer. Research has shown that problem-oriented training leads to better knowledge transfer than does memory-oriented training, and effortful processing of information results in better knowledge transfer than passive processing (Goldstone & Sakamoto, 2002).

Transfer of Learning Deficits and FASD

There have been no controlled studies of transfer of learning in FASD. Nevertheless, it is reasonable to suppose that transfer failure may account in part for the psychosocial difficulties experienced by those with FASD. Transfer deficits are tantamount to oft-cited reports that those with FASD have trouble "learning from experience" (Streissguth, 1997). They may also help account for the poor judgement characteristic of FASD. The application of sound judgement requires having

successfully stored principles or concepts from previously encountered situations similar to the one at hand, drawing parallels between those and the current situation, and figuring out how to use this information to make a sound judgement. Sound judgement also depends on intact working memory, as it requires various options along with their pros and cons to be weighed quickly and “online” (Tranel et al., 1994).

Similarly, transfer deficits may hinder social skills. At the best of times, socially appropriate behaviour is complex and requires attending and responding to multiple social cues, many of which are subtle, in a dynamic context. Individuals with social skills deficits may have difficulty understanding the basic principles of social behaviour, they may not link the current social cue with knowledge of an appropriate social behaviour, or they may fail to apply a known social skill in response to the social situation at hand. There is some literature to suggest that although social skills are amenable to training, long-term benefits ensue only when the taught skills are able to generalize to situations for which specific training has not been received (Hawkins, Catalano, Gillmore, & Wells, 1989). Compounding this, social skills deficits are exacerbated by inattention, limited self-control, and failing to take into account the consequences of one’s actions, all of which are prominent in the FASD behavioural phenotype (Streissguth, 1997).

Poor adaptive functioning and problems with daily living skills are other areas potentially affected by transfer deficits. The word *adaptive* implies making suitable to or consistent with a particular situation or use. To accomplish this, individuals must have successfully stored basic principles of adaptive functioning, recognize that the current

situation demands the application of one or more such principles, and figure out how to apply them. As with social skills, adaptive functioning and daily living skills can be taught, but long-term benefits are more likely when information can generalize to situations for which training has not occurred. Streissguth, Barr, Kogan, and Bookstein (1996) found that the daily living skills affected most in FASD involved managing money, making decisions, obtaining medical care, and grocery shopping. More basic daily living skills, such as dressing, were handled more successfully.

Executive Functions and Transfer of Learning

Rarely does the transfer of learning literature cast the processes involved as reliant on or mediated by executive functioning. One could speculate that this is because most recent research on transfer of learning is undertaken by cognitive psychologists rather than by neuropsychologists. Based on the transfer literature, however, it is reasonable to suppose that there is some overlap between executive functioning and transfer of learning. Problem solving, concept formation, and cognitive flexibility appear to be key executive contenders (Komatsu, 1992; Reeves & Weisberg, 1994; Shafto & Coley, 2003). Next, this dissertation turns to a discussion of each of these executive processes in relation to transfer of learning, and then proposes various means by which to test them experimentally in an FASD population.

Problem Solving

The concept of problem solving arises frequently in the transfer literature, and many authors contend that transfer of learning is linked inextricably with problem

solving (Gick & Holyoak, 1980; Goldstone & Sakamoto, 2002). In neuropsychology, problem solving is one of the more established executive functions (Burgess & Shallice, 2000), and likely involves a number of subcapacities (Zelazo, Carter, Reznick, & Frye, 1997). Although many different definitions exist of problem solving, most definitions incorporate the idea of an individual encountering a situation and not knowing immediately how to obtain some goal or end state (Zelazo et al., 1997). Recently, Zelazo and colleagues proposed a four-stage problem solving framework that contends that the product of all executive functioning *is* problem solving. The four stages of Zelazo's model are: (1) representing the problem and its possible solutions; (2) planning a solution from among a list of alternative solutions, and sequencing the required steps; (3) executing the plan, by keeping it in mind long enough and carrying out the prescribed behaviour; and (4) error detection and correction, whereby one evaluates one's solution, determines whether the problem has been addressed, and takes corrective action if necessary (Zelazo et al., 1997).

The transfer literature suggests that those adept at transfer are likely to be adept at problem solving. Within the context of Zelazo and colleagues framework, those able to transfer information are likely to be skilled at representing a problem and its possible solutions and should have a large stock of alternative solutions from which to choose. Indeed, in characterizing expert versus novice problem solvers, Glaser (1987) noted nearly two decades ago that it is the "initial representation that allows the expert to succeed in pursuing the better path to solution."

Concept Formation

The relevance of concept formation to transfer of learning is related closely to the possession of a large knowledge base and expertise. In the transfer literature, the deep or structural features characterizing a problem are known as schemata (Goldstone & Sakamoto, 2002). Schemata are generic concepts stored in memory, along with knowledge of how the concepts are to be used; they can be thought of as “packages of knowledge” (Komatsu, 1992). Chen and Mo (2004) noted that schema construction is facilitated in part by processing “multiple instances of diverse problems that share a similar goal structure.” That is, exposing oneself to situational diversity creates the opportunity to expand one’s conceptual base and generate predictive rules describing a diverse set of instances. Note that breadth of knowledge base is inherent in Chen and Mo’s (2004) description of schema construction. In short, concept formation is crucial to transfer of learning because the broader the pool of relevant concepts and principles, the greater the selection one will have when encountering a novel situation (Chen & Mo, 2004).

Abstract Reasoning

The process of abstract reasoning involves thinking beyond the immediate, concrete, or tangible; it involves thinking about concepts without reference to a specific instance. Clearly, this ability is important in the transfer and generalization of learning. Novel situations or problems by definition are not exactly like previously encountered ones. Therefore, although one must draw upon relevant past experiences and principles to find a solution, abstract reasoning is required to make this knowledge “fit” with the

problem at hand. This becomes more critical with increased distance between the learning and transfer situations (Chen & Mo, 2004; Haskell, 2001).

Cognitive Flexibility

Cognitive flexibility is the ability to examine some problem or situation from many points of view, particularly when dealing with novelty (Eslinger & Grattan, 1993). It is the opposite of perseveration. Eslinger and Grattan identified two kinds of cognitive flexibility, reactive and spontaneous. Reactive flexibility is the ability to alter a behavioural predisposition in response to altered contingencies. For example, if one encounters a road block on the drive home from work, reactive flexibility would facilitate the selection of an alternative route. In contrast, spontaneous flexibility refers to the idea of generating a diversity of ideas or responses, as when asked to generate as many words as possible that start with “F” (Eslinger & Grattan, 1993).

Cognitive flexibility is recognized as central to the transfer of learning (Chen, 2002; Chen & Mo, 2004). It affords the creation of flexible schemata that allow dissimilar principles to be transformed when solving novel problems (Chen, 2002). Moreover, it allows one to transform and recombine aspects from multiple schemata, thereby creating a flexible, “custom fit” schema, separated from the original context, to address the problem at hand (Chen & Mo, 2004). Note the inherence of knowledge breath in this process, which facilitates the creation of multiple schemata. Lezak (1995) wrote that conceptual inflexibility manifests as “concrete or rigid approaches to understanding and problem solving”, stimulus-bound behaviour, and the “inability to shift perceptual organization, train of thought, or ongoing behaviour to meet the varying

needs of the moment.” Interestingly, this definition bears much resemblance to some of the psychosocial difficulties documented in FASD, particularly those in adaptive functioning.

Purpose of the Dissertation

In typical neuropsychological practice, executive functions are measured with a host of standardized measures such as the WCST, the Trail Making Test, the Stroop Test, tests of verbal and nonverbal fluency, and variations of the Tower Tests. Rarely, if ever, does neuropsychological evaluation measure “transfer of learning,” largely because few tests exist to measure it. Instead, learning and memory typically are assessed separately using a selection of widely available standardized measures, and it is assumed that information gained from such measures will correspond to performance outside the test setting. In other words, it is assumed that if an individual can learn and remember information in the test environment, he or she can learn and remember information in all environments. It is important to note that this fundamentally is an issue of ecological validity, and there is an impressive literature criticizing its absence in neuropsychological testing (e.g., Sbordone & Guilmette, 1999).

The primary purpose of this dissertation was to empirically investigate anecdotal accounts that children with FASD have difficulty transferring information from one situation to another, which has been observed even in those with average-range intellectual abilities. This was investigated using three main measures of transfer: (1) a

novel experimental variation of the Tower of Hanoi; (2) a variation of Chen's (1996) Bead Retrieval Problem; and (3) the Purdue Pegboard.

The secondary purpose of this dissertation was to investigate the relationships among transfer of learning and aspects of executive functioning. As a measure of concept formation, children completed a computerized adaptation of the Picture Concepts subtest from the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV). To measure cognitive flexibility, children completed the Color-Word Interference subtest from the Delis-Kaplan Executive Function System (D-KEFS), and a computerized adaptation of the Visual-Verbal Test (Feldman & Drasgow, 1951). Descriptions of these tasks are provided below.

The Tower of Hanoi and Other Tower Tasks

The Tower of Hanoi is one of several tower tasks used in neuropsychological practice. Other forms include the Tower of London and its derivatives (e.g., the Tower of London – Revised, the Tower of London–Drexel), the California Tower Test, and the Progressive Planning Test. All tower tasks have in common an initial start state and a goal end-state that must be reached by transferring ball or disks (depending on the tower version) in the fewest number of moves possible. All tower tasks also have rules that constrain behaviour, for example by allowing only one object to be moved at a time, or by stipulating that objects not currently being moved remain on the pegs (Welsh, Satterlee-Cartmell, & Stine, 1999). Most authors contend that tower tasks measure executive functioning in general and planning in particular, with additional reliance on working memory and inhibition (Welsh & Pennington, 1988).

Recent research suggests, however, that the various tower tasks are not equivalent in the constructs they measure and rely upon. For example, in a sample of 37 young adults, Welsh et al. (1999) found only approximately 25% shared variance between the Tower of Hanoi and Tower of London–Revised (TOL–R). Moreover, over half (55%) of the variation in TOL–R performance was predicted by a combination of working memory and inhibition. Unfortunately, the authors did not report the variation in the Tower of Hanoi accounted for by working memory and inhibition. They did comment, however, that inhibition related only weakly to Tower of Hanoi performance, whereas working memory did not relate at all. The authors thus concluded that the two tower tasks rely on different cognitive processes (Welsh et al., 1999).

Similarly, Bishop, Aamodt-Leaper, Creswell, McGurk, and Skuse (2001) found in a large sample of children and adolescents that inhibition, as measured by the Same–Opposite World subtest from the Children’s Test of Everyday Attention, was unrelated to Tower of Hanoi performance. Instead, they suggested that flexibility and shifting between subgoals was a better predictor of Tower of Hanoi performance than the simple inhibition of prepotent responses. This speculation was supported by Bull, Espy and Senn (2004), who found that cognitive flexibility and shifting ability were the best predictors of Tower of Hanoi performance, particularly when children were faced with more complex problems involving goal-subgoal conflicts. Moreover, Bull and colleagues found that inhibition predicted performance on the Tower of London, but not on the Tower of Hanoi.

Other research with the Tower of Hanoi lends support for its application as a measure of transfer of learning. In particular, Welsh and Huizinga (2004) noted that inherent in the Tower of Hanoi is a single rule-based strategy that applies to all problems of all difficulty levels. They identified a recursive strategy involving five elements:

(1) recognizing that the first subgoal is to move the largest disk to its goal position; (2) moving the smaller disks out of the way; (3) building a “sub-pyramid” stack of these smaller disks on the “open” peg; (4) moving the largest disk to its goal position; and (5) repeating these steps with the “next-largest” disks and progressively smaller sub-pyramid stacks until the goal state is achieved.

In an interesting variation of the Tower of Hanoi, Welsh and Huizinga explored participants’ knowledge of this recursive strategy by analyzing their verbatim verbal responses during an additional trial administered at the end of the task. Based on their performance on this measure, participants were divided into “low strategy” or “high strategy” groups. It was found subsequently that people in the high strategy group performed significantly better within every quarter of the task and on overall task performance. Moreover, in related earlier work by the same laboratory group, it was found that explicitly teaching participants the recursive strategy led to superior task performance (Lock, Welsh, Adams, & Kurtz, 2002).

Taken together, these findings have important implications for the application of the Tower of Hanoi in this dissertation. According to Welsh’s research, understanding the recursive structure of the Tower of Hanoi facilitates solving a trial of any difficulty level. In other words, successful task performance depends on a single strategy getting

transferred from trial to trial. Further, in a population suspected to have deficits in inhibition (Mattson et al., 1999) and perhaps in working memory (Kodituwakku et al., 1995), it is desirable to have a task not dependent on these processes to measure transfer of learning. As pointed out by Welsh and colleagues, knowledge of the Tower of Hanoi's recursive strategy may indeed reduce the demands on executive functions such as working memory, inhibition, and planning (Welsh & Huizinga, 2004).

Bead Retrieval Problem

The Bead Retrieval Problem, devised by Chen (1996), requires children to retrieve a bead from the bottom of a narrow glass cylinder. In Chen's study, this could be accomplished either by filling the cylinder with water causing the bead to float to the top, or by joining two items together, thereby creating a tool long enough to retrieve the bead. The task was presented in the form of a "target" story, such that children had to help the protagonist in the story by actually solving the problem. Before receiving this task, children were read "source" stories in which similar characters solved a problem analogous to the Bead Retrieval Problem. For example, in one source story, a young girl lost a ping-pong ball in a rain barrel that was too deep for her to retrieve the ball. She found a bucket and used it to fill the rain barrel with water, until the ball began to float and she could retrieve it.

Chen (1996) manipulated superficial and structural similarities between the source and target stories to investigate the determinants of children's analogical problem solving. As might be expected, it was found that overlapping superficial and structural similarities between the source and target stories facilitated problem solving. In addition,

Chen stated that *procedural* similarity between the source and target problems facilitates transfer. That is, children benefited from “specific operational features” in the source stories that could be applied directly in the target stories.

Purdue Pegboard

The Purdue Pegboard is a test of unimanual and bimanual finger and hand dexterity (Tiffin & Asher, 1948). The test has three conditions. In the first three conditions, participants place pins into holes as quickly as possible, first with their dominant hand, then with their nondominant hand, and finally with both hands. In the fourth condition, participants make “assemblies” using pins, washers, and collars. As a measure of transfer of learning, the third and fourth conditions are of particular interest because they involve bimanual coordination. Bimanual coordination can be thought of as requiring low-level transfer of procedural-to-procedural learning, and requires interhemispheric transfer via the corpus callosum (Jeeves, 1986; Sauerwein, Nolin, & Lassonde, 1994). Interestingly, the corpus callosum appears particularly vulnerable to prenatal alcohol exposure. Numerous studies have documented callosal impairments in FASD, both morphological (Jones & Smith, 1973) and functional (Bookstein, Streissguth, Sampson, Connor, & Barr, 2002; Roebuck, Mattson, & Riley, 2002).

Although no study to date has looked specifically at Purdue Pegboard performance in children with FASD, the final two conditions of the Purdue Pegboard require bimanual coordination, and one study has found this to be impaired in FASD. Roebuck-Spencer, Mattson, Marion, Brown, and Riley (2004) found that children with

FASD were less able than control children to use bimanually coordinated hand movements to guide a cursor through angled pathways displayed on a computer screen.

Dissertation Hypotheses

The first general hypothesis was that children with FASD would show weak transfer of learning relative to control children, as measured by the three transfer of learning tasks. Because of the novel nature of this study, this hypothesis was based largely on anecdotal and observational evidence that children with FASD have difficulty with transfer of learning (Coggins et al., 1998; Streissguth, 1997).

The second general hypothesis was that children with FASD would display weak concept formation and cognitive flexibility, which together measure specific aspects of executive functioning. This hypothesis was based on existing research that has found executive function impairments in FASD.

The final general hypothesis was that performance on the transfer tasks would relate significantly to performance on the executive functioning tasks. This hypothesis was based on the transfer literature, which has identified specific factors that appear to contribute to successful transfer and which, on closer inspection, bear much resemblance to aspects of executive functioning.

Power Analysis

Bezeau and Graves (2001) noted that research produced in the field of clinical neuropsychology typically yields larger effect sizes than what is found in experimental

psychological research. Indeed, their review of 66 published articles revealed a mean effect size of 0.88. With a sample size of 16 children per group, this dissertation had a power level of 0.78 to detect an effect size of 0.88. This level of power is very similar to that recommended traditionally by Cohen to detect a large effect size (Cohen, 1988, as cited in Bezeau & Graves, 2001). In the context of the literature reviewed above, neuropsychological deficits in FASD tend to be pronounced. Therefore, a sample size of 16 children per group was likely sufficient to detect clinically significant group differences, particularly in light of the exploratory nature of this dissertation.

Methods

Participants

FASD Group

A total of 25 children with FASD participated in the study. Admission to the final FASD sample was stringent, however, resulting in a final sample size of 16 children. Foremost, all participants required a formal FASD diagnosis. Most participants (all but two in the final sample) were recruited and received their diagnosis from either the University of Victoria Fetal Alcohol Spectrum Disorder Pilot Diagnosis and Support Project, or from Dr. Jonathan Down, a local Victoria pediatrician with expertise in FASD. The diagnostic system employed by both sources was that developed by Astley and colleagues at the University of Washington (Astley, 2004). This diagnostic system assigns a 4-Digit Diagnostic Code based on the degree of expression of four features associated with FASD. These include: (1) growth deficiency; (2) FAS facial features; (3) brain damage or dysfunction; and (4) prenatal alcohol exposure. The degree to which each of these four features is present is ranked independently and assigned a score of 1 to 4, with higher numbers indicating greater pathology. Each serves as an independent line of evidence that may or may not converge upon the presence of FASD-related features (see Figure 1). Most of the children with FASD were admitted to the study only if their prenatal alcohol exposure received a Rank 3 or 4 (indicating the confirmed presence of alcohol) and if their facial dysmorphology received a Rank 2, 3, or 4 (indicating mild, moderate, or severe facial dysmorphology, respectively). The reason for allowing children with less facial dysmorphology to participate is that, as reviewed

above, not all alcohol-affected children have the facial characteristics of FASD (Mattson et al., 2001).

Two children in the final sample were recruited from a volunteer database of families interested in FASD research. These participants had received a formal FASD diagnosis from another Vancouver Island physician; however, they did not have a 4-Digit Diagnostic Code. To help substantiate the diagnosis, these children underwent computerized facial photographic analysis. Both children were found to have mild or “rank 2” facial dysmorphology. This finding, in combination with the presence of a formal FASD diagnosis, was judged as satisfactory for admission to the study.

Of the 25 initial participants with FASD, five were excluded because they were too old (13-15 years old). Another child fell below accepted criteria on the intelligence screening measures; his data were excluded. This reduced the number of acceptable participants to 19. Three children were subsequently excluded because of a questionable FASD diagnosis. One such child, who went through the University Clinic, received a diagnosis of 1-2-2-2 [Neurobehavioral disorder (alcohol exposure unknown)], indicating no growth deficiency, mild facial abnormalities, possible CNS dysfunction, and unknown prenatal alcohol exposure. A review of his data revealed that his performance departed somewhat from most of the other FASD participants; therefore, his data were excluded from the analyses. The remaining two children had received a formal FASD diagnosis from other Vancouver Island physicians. Diagnostic information on these children was sparse, with no 4-Digit Code and a strongly suspected but unconfirmed prenatal alcohol exposure history. Further, computerized facial analyses of both participants revealed

normal facial morphology, translating to a “rank 1” on the 4-Digit Diagnostic Code.

Therefore, these participants were excluded from the analyses, bringing the final sample size to 16.

Figure 1: 4-Digit Diagnostic Code Grid

4-Digit Diagnostic Code Grid									
Significant	Severe	Definite	4					4	High risk
Moderate	Moderate	Probable	3					3	Some risk
Mild	Mild	Possible	2					2	Unknown
None	None	Unlikely	1					1	No risk
Growth Deficiency	FAS Facial Features	CNS Damage		Growth	Face	CNS		Alcohol	Prenatal Alcohol

Of the 16 children in the final FASD sample, seven children were prescribed medication. Two children were taking stimulants only (Ritalin and Concerta), two children were taking a combination of risperidone and either Ritalin or Dexedrine, and one child was taking Wellbutrin. One child was taking Ritalin, risperidone, and clonidine, and another child melatonin, sodium valproate, and risperidone. Children were not expected to discontinue their medication for the study because the tasks required optimal attention and behaviour, and it was judged that withholding medication for the duration of a drug washout period (typically 24 hours for stimulants, and longer for other medications) would be too disruptive for families. One child had an additional diagnosis of attention deficit / hyperactivity disorder (ADHD); apart from this, no child in the FASD group had an additional psychiatric or neurological diagnosis. Eight of the

children in the FASD group were receiving special learning assistance in the form of special education classes, adapted or modified curricula, an individual education plan, or tutoring, whereas two children were not receiving any services. Information on learning assistance or special education was unavailable for six children.

Control Group

The second group of participants consisted of 16 community control children. From a surplus of control participants, children were matched individually to those in the FASD group based on age and gender (absolute age difference: $M = 3.60$ months, $t = -.06$, ns). Recruitment occurred from a database of participants from previous unrelated research in our laboratory, through flyers posted in community centres around Victoria, and through Internet newsgroups and discussion forums. Children in the control group were screened for prenatal alcohol exposure by asking parents to complete a childhood history questionnaire. All but one parent indicated no alcohol consumption during pregnancy. One parent report having had less than one glass of wine during the first six weeks of pregnancy, before she was aware of her pregnancy. This amount of alcohol consumption was judged as acceptable for admission to the study. When possible, control children also underwent photographic facial analysis to help substantiate the absence of prenatal alcohol exposure. Photographic data was available for 10 of the 16 participants. Two participants declined to have their picture taken because of shyness. Photographs were unavailable for four additional control participants because of technical difficulties with the camera (two participants) and time constraints (two participants). Of the 10 participants who underwent facial analysis (including the child

whose mother drank wine), none were found to have facial dysmorphology, equivalent to a “rank 1” on the facial section of the 4-Digit Diagnostic Code. In addition, all control children were screened for developmental, neurological, behavioural, and psychiatric status using a child history questionnaire. No control participant was affected by any of these conditions, nor was any control participant taking psychotropic medication. In addition, no child in the control group was receiving current learning assistance at school; however, four children had received learning assistance or tutoring in previous grades.

Table 3 outlines demographic and other characteristics of the participants.

Procedure

Most of the control participants and half of the FASD participants were tested individually at the University of Victoria in one 1.75 to 2.0 hour session, with short breaks as needed. The University testing environment consisted of two rooms. The main testing room contained a table at which non-computerized tasks were performed, along with a desk and computer at which computerized tasks were performed. A second room was also used briefly to complete the “transfer” version of the Tower of Hanoi. Three of the control participants and the other half of the FASD participants were tested individually in a quiet location in their home or in a small travel trailer set up as a “mobile test centre.” Remote testing was necessary because many interested families did not live in Victoria and could not make the trip to the University.

Prior to embarking on the research tasks, children and parents met with the principal investigator to discuss the nature of the study and to review the informed

Table 3. Participant demographics, FASD diagnostic information, and other characteristics.

	FASD	Control
Age in years [Mean (SD), Range]	10:05 (1.26), 7-12	10:08 (1.36), 7-12
Gender ratio (male:female)	9:7	9:7
<i>4-Digit Diagnostic Codes and Names (number of children)</i>		
Static encephalopathy (alcohol exposed)	6	–
Sentinel physical finding(s) / neuro-behavioral disorder (alcohol exposed)	4	–
Sentinel physical finding(s) / static encephalopathy (alcohol exposed)	1	–
Sentinel physical finding(s) / neuro-behavioral disorder (alcohol exposure unknown)	1	–
Neurobehavioral disorder (alcohol exposed)	1	–
Partial FAS (alcohol exposed)	1	–
4-Digit Code unavailable	2	–
Vocabulary scaled score [Mean (SD), Range]	6.31 (2.18), 1-11	11.31 (2.55), 8-18
Matrix Reasoning scaled score [Mean (SD), Range]	6.00 (2.73), 1-11	13.13 (2.42), 9-18
Estimated IQ [Mean (SD), Range]	6.16 (1.64), 3.50 - 8.50	12.22 (2.16), 8.5 - 18
<i>Ethnicity (number of children)</i>		
Asian	0	1
Caucasian	8	12
First Nations	8	0
South African Indian	0	1
Mixed Caucasian + Other	0	2

consent procedures. Written consent was obtained from the parent or legal guardian of each child (Appendix C), and each child also provided written consent and verbal assent (Appendix D). All children then completed the tasks in an identical order. As an honorarium for participating, each parent and child received \$5.00, and each child received a lollipop and a toy of their choice from large grab-bag of toys. Parents, too, were offered a lollipop, but most graciously declined.

Measures

Intellectual Ability

All children completed the Vocabulary and Matrix Reasoning subtests from the WISC-IV as a screening measure of intelligence. These subtests were selected because they have the highest correlations with the FSIQ relative to other WISC-IV subtests (Wechsler, 2003). Together, they provide an estimate of verbal and nonverbal reasoning abilities. The use of Wechsler scale short forms is well established in the literature. Research with the Vocabulary and Block Design subtest combination from previous versions of the Wechsler Intelligence Scale for Children suggest satisfactory correlations in the range of 0.77 to 0.88 with FSIQ (Herrera-Graff, Dipert, & Hinton, 1996; Ryan, 1981). Although this two-subtest combination has the potential to misclassify individuals, it is considered an appropriate screening measure of intelligence (Herrera-Graff et al., 1996). No study to date has examined the correlation between the Vocabulary / Matrix Reasoning combination and the WISC-IV FSIQ. However, these particular subtests have similar or stronger correlations with FSIQ relative to the

correlation between FSIQ and the Vocabulary / Block Design combination from previous versions of the Wechsler scales (Wechsler, 2003).

In the Vocabulary subtest, children were asked to define words of increasing complexity. The test was discontinued when a child was unable to correctly define five consecutive words. Scores of 0, 1, or 2 were assigned for each item according to definitional criteria detailed in the WISC-IV manual. The summary measure was the sum of all of these scores.

In the booklet version of Matrix Reasoning from the WISC-IV, children are presented with an incomplete picture at the top of a page and five response choices below. They are asked to point to the one picture from the bottom that best completes the picture at the top. The task is discontinued when a child responds incorrectly to five consecutive items. This task was adapted for computer and structured identically to the booklet version; however, instead of pointing to the selected picture, children clicked it with a mouse. The summary measure was the total number of items answered correctly. Although computerizing this task may affect the suitability of using the WISC-IV normative data, this issue was considered to have a negligible influence on the dissertation results. This judgement was made foremost because there was no *a priori* reason to assume that displaying the matrix reasoning stimuli on a computer would alter the task demands relative to displaying the stimuli in booklet form. Further, because both groups of children received the same task, and since the groups were matched by age and gender, any artifacts from computerizing the task would affect both groups equally.

According to research by Mattson and colleagues (e.g., Mattson & Riley, 1998), it is common to obtain an uneven pattern of cognitive development in children with FASD, such that verbal or nonverbal abilities may be discrepant. Therefore, children were excluded from the study only if their performance on *both* Vocabulary and Matrix Reasoning fell below scaled scores of 6.

Tower of Hanoi - Experimental Variation

A variation of the Tower of Hanoi was created as a novel, experimental measure of transfer of learning. Two versions of the task were administered, a “learning” version and a “transfer” version. The Learning Condition consisted of a homemade, hands-on modification of the Tower of Hanoi apparatus. Rather than using disks of increasing size as per the traditional Tower of Hanoi, the learning task featured three or four nested plastic cups. Note that according to the transfer literature reviewed above, the modification to this task would be considered surface versus structural. Apart from this physical modification of the stimuli, the task rules were identical to the traditional Tower of Hanoi. Children began with various start states, arranged according to the standard task instructions, and were asked to duplicate a depicted goal state using the fewest number of moves possible. In a typical Tower of Hanoi administration, participants receive only minimal introductory instructions; however, because the purpose of this dissertation was to measure transfer of learning, it is crucial that deficits, if found, truly reflect a failure of *transfer* versus a failure of *learning*. Therefore, all participants completed this first learning task aided by abundant demonstrations, practice, repetition, and feedback. In addition, important strategies for solving the task were made explicit

(e.g., “First we have to put the biggest cup in its place, because then the smaller ones can go inside”), and children were encouraged to verbalize these strategies repeatedly as the task proceeded. A total of three problems were administered. Younger children (age 7 to 9) received three problems requiring three, five, and seven moves to reach the goal state. Older children (age 10 to 12) received three problems requiring five, seven, and nine moves to reach the goal state. The criterion for successful completion of a particular problem was two consecutive successful completions.

The Transfer Condition of the Tower of Hanoi consisted of three or four large plastic Tupperware containers; otherwise, it was identical to the Learning Condition in terms of the start and goal configurations, and number of moves. To change the context of this transfer task relative to the previous learning task, children completed the transfer task in a different location. As per standard Tower of Hanoi instructions, children received only minimal introductory instructions. No further assistance was provided.

On both task versions, children received as many trials as necessary to successfully complete a given problem twice consecutively. Performance was scored based on the procedure described by Welsh et al. (1999). Seven points were awarded if a particular problem was solved on trials 1 and 2, six points on trials 2 and 3, five points on trials 3 and 4, four points on trials 4 and 5, three points on trials 5 and 6, two points on trials 7 and 8, and one point beyond 8 trials. Thus, based on a total of three problems and a maximum score of six points per problem, total scores ranged from 0 to 21.

An additional variable also was created to represent children’s transfer performance based on their learning performance. This was accomplished using

regression analysis, with performance on the Transfer Condition as the dependent variable, and performance on the Learning Condition as the predictor variable. The new variable was created from the unstandardized residuals of the regression analysis, which reflect the actual value of children's transfer performance minus the value predicted by the regression equation. For ease of reference, this derived variable was called the "Tower of Hanoi Predicted Transfer Score." This variable provides a purer indication of transfer of learning because it reflects children's transfer performance after taking into consideration their learning performance.

Bead Retrieval Problem

This task served as the second transfer measure (Appendix E). Children were read a *source story* in which a group of children were playing ping-pong and accidentally lost their ball in a large rain barrel. Unable to retrieve the ball by hand because of the rain barrel's depth, the children in the story arrived at the solution of filling the rain barrel with water using a bucket, causing the ping-pong ball to float to the top of the barrel so that they could reach it. Along with hearing the story, children saw coloured pictures, printed on 3.5" x 4.0" cards, depicting its major components. To ensure that children had paid attention to the story and understood its central points, three content questions were asked at the end: (1) What did the children lose?; (2) Where did they lose it?; and (2) How did they get it back?

Next, participants were read a *target story* in which a child was playing with beads and accidentally dropped one of them into a narrow tube. The child in the story was unable to retrieve the bead by hand and could not invert the tube. At this point in the

task, a tall, narrow plastic tube containing a floatable wooden bead was placed in front of the child along with a separate container of objects that the child could use to retrieve the bead. The only way of retrieving the bead was to squeeze water into the tube using a squeezable water container. The container also held a variety of nonessential “distractor” items selected to give the appearance of having the potential to retrieve the bead. These items included scissors, string, a tape dispenser, paper clips, and a narrow stick. As these various objects were slid in front of the child, he or she was asked to “help” the child in the story retrieve the bead as quickly as possible, using any of the objects inside of the container. The ideal solution was to immediately select the water container and squeeze water into the tube.

To address possible transfer failure, and in keeping with the substantial body of research showing that successful transfer often requires cueing, two levels of prompting were available if the child did not retrieve the bead within two and four minutes, respectively. After two minutes, children were presented with a general cue directing them to think about first story they heard. After four minutes, children were presented with a more specific cue, directing them to think about how the child in the first story retrieved the ping-pong ball.

Scoring was based both on the total amount of time required to retrieve the bead and according to points awarded. Three points were awarded if a child solved the problem without a cue, two points or one point if one or two cues were required respectively, and no points if the child could not solve the problem.

Purdue Pegboard

This task served as the final transfer measure. The Purdue Pegboard consists of a board with two parallel columns of 25 small holes with four cups at the top of the board. The left- and right-hand cups each contain 25 metal pegs, and the middle two cups contain metal washers and collars. In the first three subtests, children were asked to insert as many pegs as possible into the holes using, sequentially, their dominant hand, nondominant hand, and both hands. The fourth subtest involved coordinating both hands to create “assemblies,” which consisted of a pin, a washer, a collar, and another washer (Spren & Strauss, 1998). The first three subtests had a 30-second time limit, and were scored by counting the number of pegs (subtests 1 and 2) or pairs of pegs (subtest 3). The fourth subtest had a 60-second time limit, and was scored by counting the number of individual assembly components properly placed.

As was done for Tower of Hanoi, an additional variable was created to represent children’s transfer performance on the Purdue Pegboard based on their learning performance. This was accomplished using regression analysis, with performance Condition 3 (both hands) entered as the dependent variable, and performance on Conditions 1 and 2 (each hand separately) entered simultaneously as predictor variables. The new variable was created from the unstandardized residuals of the regression analysis, which reflect the actual value of children’s performance on Condition 3 minus the value predicted by the regression equation. For ease of reference, this derived variable was called the “Purdue Pegboard Predicted Transfer Score.” Of note, the fourth “Assembly” condition was not considered in this variable because it is quite different

from the first three subtests, and was judged to involve new learning rather than transfer of learning.

Picture Concepts

This task, selected as a measure of concept formation, is one of the standardized subtests on the WISC-IV and was adapted for computer. In the booklet version of this task, children are presented with pages containing two or three rows of pictures. One picture from each row is related semantically to one picture from each of the other rows, and children must identify the corresponding pictures by pointing to them. In the computer adaptation, stimuli were presented on a computer monitor using an identical arrangement to the booklet version, and children indicated their responses by clicking with a mouse. Each trial yielded a score of 0 or 1, depending on whether the child identified all of the corresponding pictures. The summary measure on this task was the total number of items answered correctly.

Color-Word Interference Test

This Stroop-like task is part of the D-KEFS test battery, and was selected as a measure of cognitive flexibility. The test consisted of four conditions, in which children: (1) named 50 colour patches; (2) read 50 colour words printed in black ink; (3) named the colour of ink in which 50 colour words were printed (e.g., had to say “red” to the word blue printed in red ink); and (4) switched between naming the colour of ink in which 50 colour words were printed (as in part 3), and reading the actual words (ignoring the colour) when they encountered words printed inside of a box. Each of the four conditions was timed, and children were instructed to proceed as quickly as possible.

Conditions 1 and 2 are considered control conditions, whereas conditions 3 and 4 are thought to measure inhibition and flexibility.

Each condition yielded three scores: time taken; number of self-corrected errors; and number of uncorrected errors. These scores were subsequently used to derive four summary variables: two ratios based on time; and two difference scores based on number of errors. In essence, these derived variables addressed: (1) How much longer it took to complete each of the inhibition and flexibility conditions relative to the first two conditions; and (2) How many more errors were made on each of the inhibition and flexibility conditions relative to the first two conditions. These kinds of calculations are often used in Stroop paradigms, and are suggested to be sensitive to age-related changes in performance (Graf, Uttl, & Tuokko, 1995).

The derived variables were calculated as follows: (1) a “Stroop inhibition ratio” was calculated by averaging the time taken on the first two conditions, and then dividing this into the time taken on the third condition (i.e., mean time of condition 3, divided by mean time of conditions 1 and 2); (2) a “Stroop flexibility ratio” was calculated similarly, using condition 4 (i.e., mean time of condition 4, divided by mean time of conditions 1 and 2); (3) an “inhibition error difference score” was calculated by subtracting the total number of errors from condition 3 from the average number of errors in conditions 1 and 2; and (4) a “flexibility error difference score” was calculated as directly above, but with condition 4 (i.e., total number of errors on condition 4 minus the average number of errors on conditions 1 and 2).

Visual-Verbal Test

This task served as an additional measure of flexibility. In the booklet version of this task, children see a series of cards each depicting four objects. They are asked to select three objects that match each other on one dimension, followed by three objects that match each other on another dimension. Thus, two of objects must be selected twice according to a different dimension (e.g., size followed by colour). This task was adapted for computer and structured identically to the booklet version; however, the task was shortened from 42 to 21 trials. Children indicated their responses by using a mouse to click on the objects and describing how the particular objects were alike. To prevent guessing, items were counted as correct only if children provided correct verbal responses. Three summary scores were derived from this task: (1) Single Miss, indicating the failure of one concept on a card; (2) Double Miss, indicating the failure of both concepts on a card; and (3) a Total Miss score. The Single- and Double-Miss scores were obtained by summing the number of cards in which one or two concepts were missed, respectively. The Total Miss score was obtained by adding the Single Miss total and twice the Double Miss total (i.e., $TM = SM + 2DM$), and served as the primary summary measure for this task.

Transfer of Learning Questionnaire

A novel transfer of learning questionnaire, called the “Children’s Learning Questionnaire” (CLQ), was created to obtain parent and caregiver perceptions of a child’s transfer of learning abilities in everyday life (Appendix F). Twenty-two questions were created based on variables that research has identified as important for transfer to

occur, on anecdotal reports of how transfer difficulties appear in FASD, and on behaviours that presumably would occur in the presence of transfer deficits. As such, questions were designed to probe behavioural indicators of knowledge base, inhibitory control, flexibility, and direct transfer of learning. Efforts were made to set the readability of the CLQ at about a Grade 6-8 level. Based on pilot testing with three parents whose children were being evaluated for FASD, and who were not part of the study, the content of the initial draft appeared appropriate. Therefore, the only revision involved adding shading to every second question to improve clarity.

Individual CLQ questions were answered on a scale of 0 to 3, with higher numbers indicating greater presence of a particular behaviour. The summary measure for this questionnaire was the sum of all of the questions, including seven reverse-scored questions. Higher values indicated better perceived transfer abilities.

Adaptive Functioning Questionnaire

Parents or guardians completed the Adaptive Behavior Assessment System - Second Edition (ABAS-II; Harrison & Oakland, 2003). This standardized questionnaire yields parent or caregiver perceptions of a child's adaptive functioning skills in everyday life. It focusses on independent behaviours and assesses what a child is capable of in everyday life, what the child may be capable of, and what behaviours the child displays without assistance from others. The ABAS-II contains 211 questions in nine adaptive skill areas: communication, community use, functional academics, home living, health and safety, leisure, self-care, self-direction, and social skills. Questions are answered on a scale of 0 to 3. Individual values indicate whether a child is able to perform an activity

independently and, if so, how frequently that activity is performed when needed. Higher values indicate better adaptive skills in the particular area measured. Published data on the ABAS-II indicate strong psychometric properties at both the subscale and composite levels (Harrison & Oakland, 2003).

Results

Gender

Preliminary analyses with all measures were conducted to test for gender effects. The genders did not differ reliably on any variable; therefore, gender effects were not considered in subsequent analyses.

Intellectual Ability

An analysis of variance (ANOVA) revealed that children with FASD obtained significantly lower scaled scores on both Vocabulary [$F(1,30) = 35.53, p < 0.001$, Effect size (ES) = 2.11] and Matrix Reasoning [$F(1,30) = 70.00, p < 0.001, ES = 2.96$]. An estimate of general intelligence was calculated by averaging each child's scaled score on both tests. This estimate captured both verbal and nonverbal abilities, which are traditionally combined when measuring intelligence. The groups also differed significantly on this measure [$F(1,30) = 79.94, p < 0.001, ES = 3.16$]. When appropriate, this value was used as a covariate in subsequent analyses of covariance (ANCOVA) to account for group differences in intelligence.

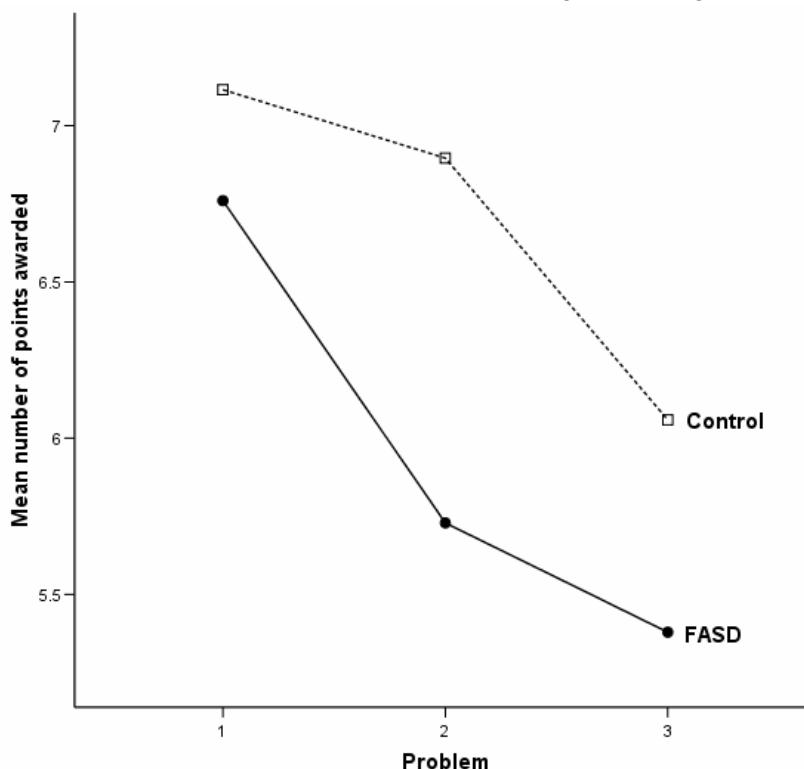
Whether or not one should statistically control for intelligence in this kind of study has not been fully resolved in the literature. There are strengths and drawbacks to either approach. This important issue is addressed more thoroughly in the latter half of the Discussion.

Transfer of Learning Tasks

Tower of Hanoi

On the initial “learning” version of the task, an analysis of covariance (ANCOVA) [2 (groups) x 3 (problems)], with intelligence as the covariate, did not reveal a significant main effect for group [$F(1,29) = 1.97, ns, ES = 0.50$], nor was the group by problem interaction significant [$F(2,58) = .50, ns, ES = 0.25$]. However, the main effect for problem was significant [$F(2,58) = 4.20, p = 0.02, ES = 0.72$]. Taken together, these results suggest that both groups of children mastered the Learning Condition of the Tower of Hanoi at a similar rate and that it took more trials to reach criterion on later problems. Figure 2 depicts these results.

Figure 2. Mean number of points awarded per problem on the Learning Condition of the Tower of Hanoi, after controlling for intelligence.

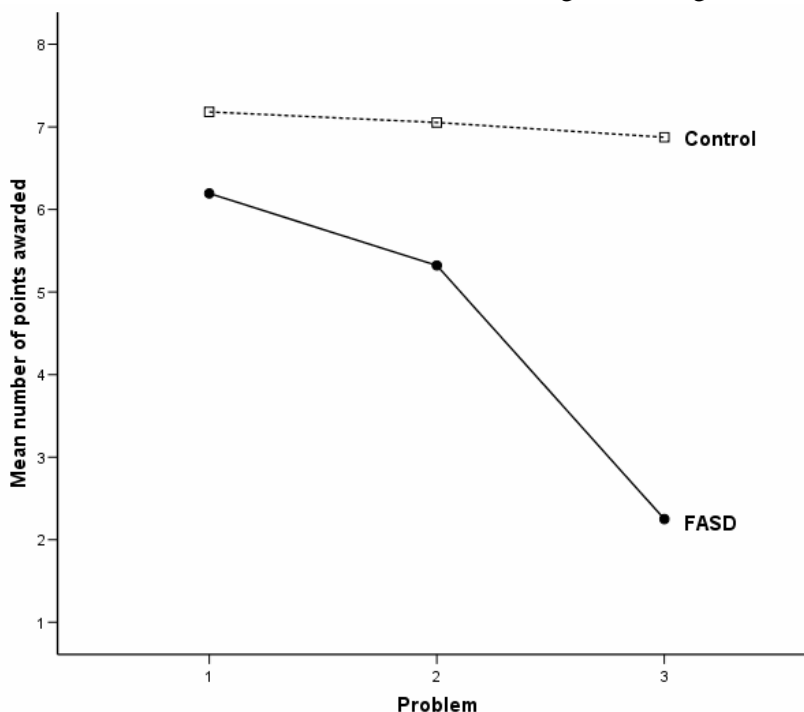


On the “transfer” version of the task, an ANCOVA [2 (groups) x 3 (problems)] revealed a significant main effect for group [$F(1,29) = 16.75, p < .001, ES = 1.45$], indicating that, overall, control children demonstrated better performance on this variation of the Tower of Hanoi. The group by problem interaction also was significant [$F(2,58) = 6.17, p < .01, ES = 0.88$]; whereas control children demonstrated stable performance across all three problems, the performance of children with FASD degraded during later problems. Further analyses revealed that the groups did not differ significantly on the first (and simplest) transfer problem, but did differ significantly on the second and third transfer problems. Parenthetically, two children with FASD were unable to complete the third transfer problem set. The results of the Transfer Condition are depicted in Figure 3, and Table 4 presents descriptive statistics of both versions of the Tower of Hanoi.

Table 4. Descriptive statistics for the number of points awarded on both versions of the Tower of Hanoi.

	FASD			Control		
	<i>M</i>	SD	Range	<i>M</i>	SD	Range
Learning Problem 1	6.88	0.34	6-7	7.00	0.00	7-7
Learning Problem 2	5.69	1.54	1-7	6.94	0.25	6-7
Learning Problem 3	4.88	1.86	1-7	6.56	0.73	5-7
Transfer Problem 1	6.44	1.09	3-7	6.94	0.25	6-7
Transfer Problem 2	5.38	1.63	1-7	7.00	0.00	7-7
Transfer Problem 3	2.75	2.21	1-7	6.38	1.02	4-7

Figure 3. Mean number of points awarded per problem on the Transfer Condition of the Tower of Hanoi, after controlling for intelligence.

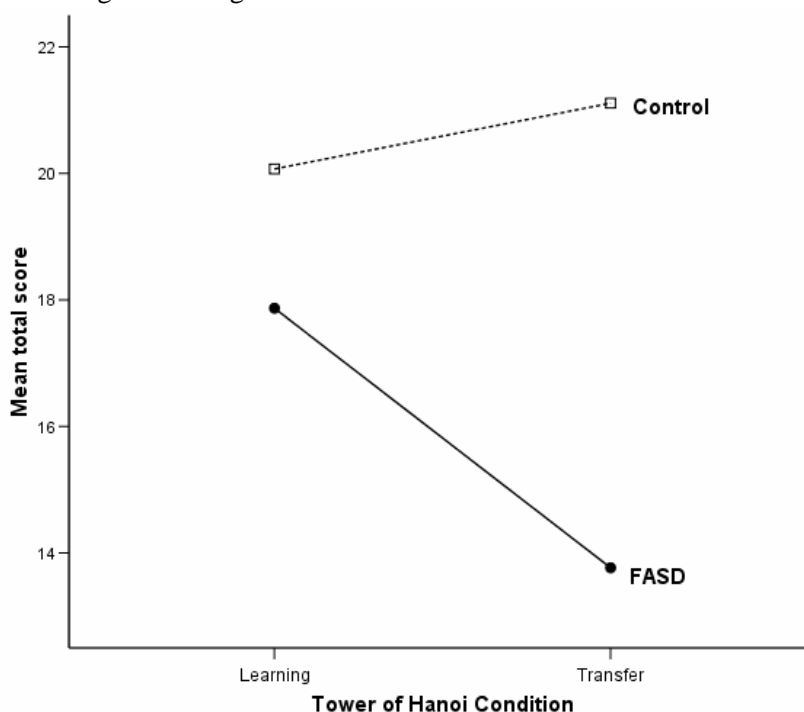


An additional ANCOVA was conducted with the regression-based “Tower of Hanoi Predicted Transfer Scores.” This analysis revealed a significant main effect for group [$F(1,29) = 8.84, p < .01, ES = 1.05$], indicating that control children demonstrated better transfer on the Tower of Hanoi relative to their initial learning performance. This effect was even larger when intelligence was not controlled [$F(1,30) = 10.72, p < .01, ES = 1.16$].

In a final analysis, two “total score” summary measures were calculated for each version of the Tower of Hanoi by adding the number of points awarded from each problem. This total score for each version was then analyzed in a 2 (group) x 2 (version)

ANCOVA, with repeated measures on the second factor. This analysis revealed that children with FASD performed significantly weaker on the Transfer Condition of the Tower of Hanoi relative to the Learning Condition [$F(1,29) = 6.64, p = .02, ES = 0.91$]. By comparison, control children demonstrated very similar performance between the two versions. In fact, their performance improved slightly, though not significantly. These results are portrayed in Figure 4.

Figure 4. Mean total score on each condition of the Tower of Hanoi after controlling for intelligence.



Observationally, during the transfer task most control children recognized that they were engaged in a task similar to one they had just completed. The majority of control children made spontaneous verbal remarks such as, “We just did this!” or “We’re

playing this *again?!?*” Very few children (approximately 2-3) in the FASD group made similar remarks. Such remarks, so dichotomously distributed between the two groups of children, were not anticipated in the study’s design and as such were not formally recorded.

Bead Retrieval Problem

Descriptive statistical analyses of the data from this task revealed a distribution that was positively skewed in both groups. In particular, three control children took much longer to complete the task compared to other children from both groups. Because cues were provided on the basis of time, which in turn affected the number of points earned, there was no variance in the points awarded to children with FASD; all children in this group received a perfect score (see Table 5). This violates the homogeneity of variance assumption in parametric statistical analyses, and therefore nonparametric analyses were conducted. A Mann-Whitney U test showed that the groups did not differ significantly with respect to how long they took to solve the bead retrieval problem (exact significance = 0.31). An additional analysis was conducted with the number of items used to complete the task. These data were transformed into a dichotomous variable to reflect whether children used only water to complete the task, or whether they first tried other items. A chi-square analysis of this variable showed that the groups did not differ reliably (chi-square = 0.45).

Table 5. Descriptive statistics for the Bead Retrieval Problem.

	FASD			Control		
	<i>M</i>	SD	Range	<i>M</i>	SD	Range
Time taken (sec)	25.88	30.31	1-117	51.06	61.02	1-185
Number of items used	2.19	1.42	1-5	2.50	1.32	1-5
Number of points	3.00	0.00	2-3	2.81	0.40	2-3

Purdue Pegboard

After controlling for intelligence, significant group differences were not observed on any subtest of the Purdue Pegboard, nor on the calculated “Purdue Pegboard Predicted Transfer Score” [$F(1,29) = 0.08$ to 1.90 , *ns*, $ES = 0.10$ to 0.49]. On the final condition, which involved creating “assemblies” with both hands, an ANOVA showed that control children outperformed those with FASD when intelligence was not accounted for [$F(1,30) = 6.28$, $p = 0.02$, $ES = 0.89$]. These results are presented in Table 6.

Appendices A and B present correlations among all of the transfer tasks along with the ABAS-II in control children and in children with FASD, respectively.

Table 6. Descriptive statistics for the Purdue Pegboard.

	FASD			Control		
	<i>M</i>	SD	Range	<i>M</i>	SD	Range
Dominant hand	13.13	2.25	9 - 18	14.00	1.59	11 - 16
Nondominant hand	12.50	1.86	10 - 17	13.13	1.15	11 - 15
Both hands	10.50	1.79	8 - 15	10.69	1.54	7 - 13
Assemblies	24.81	6.45	13 - 36	29.69	4.35	23 - 37

Executive Function Tasks

To determine whether there was an omnibus group difference on the executive function measures, a multivariate analysis of covariance (MANCOVA) was conducted with the six summary measures from Picture Concepts, the Color-Word Interference Test, and the Visual-Verbal Test, along with intelligence as a covariate. This analysis showed that, overall, the groups differed significantly on the executive function tasks (Wilk's Lambda = 0.60, $F(6,24) = 2.72$, $p = 0.04$, ES = 0.58]. When intelligence was not accounted for, this effect was larger (Wilk's Lambda = 0.31, $F(6,25) = 9.09$, $p < 0.001$, ES = 1.07). Given the presence of this omnibus relationship, separate univariate analyses were conducted with each of the three executive functioning tasks. Table 7 presents descriptive statistics for these measures. Tables 8 and 9 present inter-correlations among the tasks for control children and for children with FASD.

Picture Concepts

An ANCOVA, with intelligence as a covariate, showed that the groups did not differ significantly after controlling for intelligence [$F(1,29) = 0.13$, *ns*, ES = 0.13]. When intelligence was not accounted for, control children obtained significantly higher scores [$F(1,30) = 13.18$, $p < 0.001$, ES = 1.28].

Color-Word Interference Test

An ANCOVA, with intelligence as a covariate, revealed that the two groups of children did not differ significantly on the inhibition condition [time ratio: $F(1,29) = 1.04$, *ns*, ES = 0.36; error difference score: $F(1,29) = 1.46$, *ns*, ES = 0.43]. On the

Table 7. Descriptive statistics for Picture Concepts, the Color-Word Interference Test, and the Visual-Verbal Test.

	FASD			Control		
	<i>M</i>	SD	Range	<i>M</i>	SD	Range
Picture Concepts Total Score	13.88	3.79	7-20	18.75	3.80	9-25
Color-Word Interference Test						
Inhibition time ratio	2.48	0.61	1.61-4.00	2.08	0.43	1.35-2.68
Inhibition error difference score	9.66	5.71	2.25-22.00	3.81	2.59	1.00-9.75
Flexibility time ratio	2.37	0.30	1.64-2.83	2.29	0.35	1.65-3.04
Flexibility error difference score	13.41	7.85	3.50-36.25	6.56	4.64	1.50-20.75
Visual-Verbal Test Total Score	29.75	3.89	22-37	37.47	3.24	30-42

flexibility condition, control children performed more quickly [$F(1,29) = 9.97, p < 0.01$, $ES = 1.12$], but the two groups did not differ significantly in their relative number of errors [$F(1,29) = 1.59, ns$, $ES = 0.45$]. These results suggest that, compared to their own performance on the first two control conditions, children with FASD took significantly longer on the flexibility condition, but they did not make significantly more errors.

When intelligence was not accounted for, control children performed the inhibition condition more quickly [$F(1,29) = 4.69, p = 0.04$, $ES = 0.77$] and made fewer errors [$F(1,29) = 13.88, p < 0.01$, $ES = 1.32$] relative to their performance on the control conditions. Similarly, they made fewer relative errors on the flexibility condition [$F(1,29) = 9.01, p < 0.01$, $ES = 1.06$]. However, the groups did not differ on the relative time taken on the flexibility condition [$F(1,29) = 0.57, ns$, $ES = 0.27$].

Table 8. Correlations among Picture Concepts, the Color-Word Interference Test, and the Visual-Verbal Test in control children.

	Picture Concepts Total Score	CWIT Inhibition Time Ratio	CWIT Inhibition Error DS	CWIT Flexibility Time Ratio	CWIT Flexibility Error DS	VVT Total Score
Picture Concepts Total Score	–					
CWIT Inhibition Time Ratio	0.30	–				
CWIT Inhibition Error DS	-0.23	0.24	–			
CWIT Flexibility Time Ratio	0.21	0.05	-0.02	–		
CWIT Flexibility Error DS	-0.14	-0.17	0.16	0.25	–	
VVT Total Score	0.39	0.37	0.11	0.38	0.19	–

Note: CWIT = Color-Word Interference Test; VVT = Visual-Verbal Test; DS = Difference Score

Table 9. Correlations among Picture Concepts, the Color-Word Interference Test, and the Visual-Verbal Test in children with FASD.

	Picture Concepts Total Score	CWIT Inhibition Time Ratio	CWIT Inhibition Error DS	CWIT Flexibility Time Ratio	CWIT Flexibility Error DS	VVT Total Score
Picture Concepts Total Score	--					
CWIT Inhibition Time Ratio	-0.27	--				
CWIT Inhibition Error Difference	-0.35	0.43	--			
CWIT Flexibility Time Ratio	.00	0.48	-0.16	--		
CWIT Flexibility Error Difference	-0.18	-0.07	0.56*	-0.32	--	
VVT Total Score	0.21	-0.07	0.04	0.15	-0.06	--

Note: CWIT = Color-Word Interference Test; VVT = Visual-Verbal Test; DS = Difference Score
* $p < 0.05$

Visual-Verbal Test

An ANCOVA, with intelligence as a covariate, showed that the groups did not differ significantly on this task after controlling for intelligence [Total Score: $F(1,29) = 3.53$, *ns*, $ES = 0.66$]. Before controlling for intelligence, however, control children made fewer errors than did children with FASD [$F(1,30) = 36.85$, $p < 0.001$, $ES = 2.15$].

Parent Questionnaires

Adaptive Functioning Questionnaire

Children with FASD were rated as having significantly weaker adaptive functioning abilities in all domains before controlling for intelligence, and in several specific domains after controlling for intelligence. Because the ABAS-II measures nine skills, a more conservative alpha value of 0.01 was selected to reduce the probability of Type I error. These results are displayed in Table 10.

Transfer of Learning Questionnaire

An ANCOVA of CLQ total scores indicated that children with FASD were rated as having significantly weaker transfer of learning abilities in everyday life according to this exploratory questionnaire [$F(1,29) = 19.67$, $p < 0.001$, $ES = 1.57$]. When intelligence was not controlled, this effect was even larger [$F(1,30) = 91.29$, $p < 0.001$, $ES = 3.38$]. Interestingly, there was no overlap between the distribution of scores for each group; this is depicted in Figure 5.

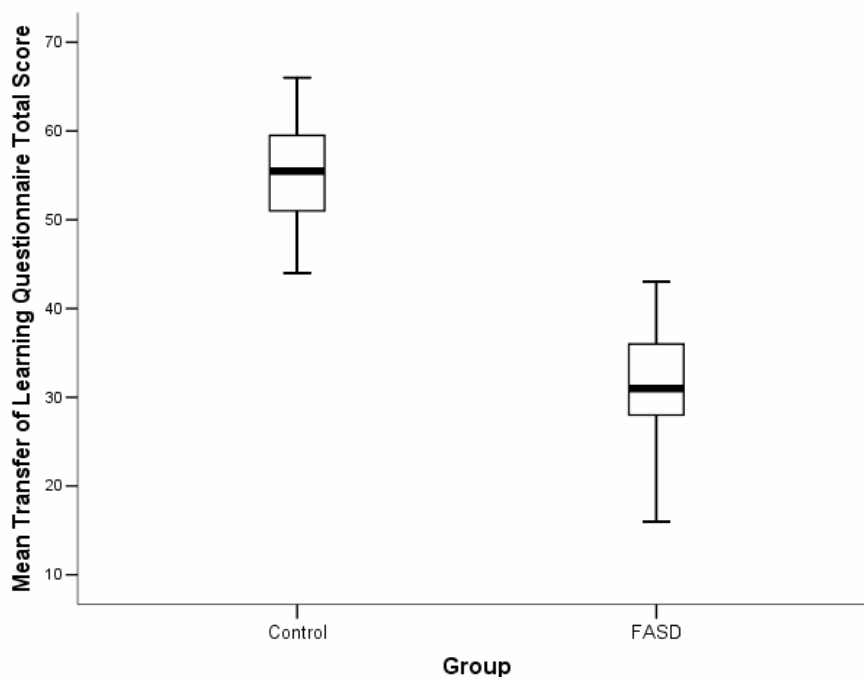
Table 10. ABAS-II scaled scores and statistical analyses after controlling for intelligence.

	FASD		Control		Group Statistics		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> (1,29)	<i>p</i>	<i>ES</i>
Communication	6.00	2.13	11.63	2.33	14.55	< 0.001	1.35
Community Use	5.75	2.77	9.38	3.70	2.59	ns	0.57
Functional Academics	4.56	1.93	9.63	2.85	5.13	ns	0.80
Home Living	4.56	3.60	7.31	3.26	1.88	ns	0.48
Health and Safety	5.75	2.46	9.38	1.78	10.08	< 0.001	1.12
Leisure	6.44	2.63	11.19	1.68	7.95	< 0.01	1.00
Self-Care	6.50	3.76	9.06	3.04	4.36	ns	0.74
Self-Direction	4.06	3.51	9.31	2.77	6.37	ns	0.89
Social	4.50	2.94	10.63	2.78	22.64	< 0.001	1.68

Correlation analyses were also conducted to explore the relationship between CLQ scores and other measures in the study. Because there were such extreme group differences on the CLQ, these correlations were conducted separately for each group. In children with FASD, CLQ scores were correlated significantly and negatively with performance on the Learning Condition of the Tower of Hanoi ($r = -0.53$) and with errors on the Stroop flexibility ratio. In other words, higher parental ratings of transfer ability were associated with weaker performance on the Learning Condition of the Tower of Hanoi, and with fewer errors on the Stroop flexibility condition. In control children, CLQ scores correlated significantly with time taken on the Bead Retrieval Problem, and also with the social skills subscale on the ABAS-II. These findings suggest that more favourable parental ratings of everyday transfer abilities were actually associated with

poorer performance on the Bead Retrieval Problem, but with stronger parental ratings of social abilities. These findings are presented in Table 11.

Figure 5: Mean total scores on the Children's Learning Questionnaire.



Relationships between Transfer and Executive Functioning

Further analyses were conducted to investigate whether transfer ability related to executive functioning. This was accomplished through separate regression analyses in which performance on a particular transfer task was regressed onto age and intellectual ability. Next, Picture Concepts raw score, Stroop Flexibility Ratio, Stroop Flexibility Errors, and the Visual-Verbal Test Total Score were entered together as additional predictor variables.

Tower of Hanoi. After controlling for age and intelligence, performance on the executive function tasks did not significantly predict performance on either version of the Tower of Hanoi [Learning Condition R^2 change: $F(4,25) = 1.91$, *ns*, $ES = 0.49$; Transfer Condition R^2 change: $F(4,25) = 0.58$, *ns*, $ES = 0.27$], or the calculated “Tower of Hanoi Predicted Transfer Score” [R^2 change: $F(4,25) = 0.78$, *ns*, $ES = 0.31$].

Without controlling for intelligence, performance on the executive functioning tasks significantly predicted performance on the Transfer Condition of the Tower of Hanoi [R^2 change: $F(4,26) = 3.03$, $p = 0.04$, $ES = 0.62$], but not on the Learning Condition [R^2 change: $F(4,26) = 2.44$, *ns*, $ES = 0.5$] or the “Tower of Hanoi Predicted Transfer Score” [R^2 change: $F(4,26) = 1.72$, *ns*, $ES = 0.46$].

Based on these findings, further regression analyses were conducted to determine which particular aspects of executive functioning were related to Tower of Hanoi performance without controlling for intelligence. Rather than using the group of executive function tasks as a single predictor, each task was entered into the regression equation one by one in separate analyses. According to these analyses, the Visual-Verbal Test emerged as the only significant predictor of the Tower of Hanoi when intelligence was not taken into consideration [Learning Condition R^2 change: $F(1,29) = 6.97$, $p = 0.01$, $ES = 0.93$; Transfer Condition R^2 change: $F(1,29) = 12.63$, $p < 0.001$, $ES = 1.26$; Tower of Hanoi Predicted Transfer Score R^2 change: $F(1,29) = 4.47$, $p = 0.04$, $ES = 0.85$].

Bead Retrieval Problem. After controlling for age and intelligence, performance on the executive function tasks did not significantly predict performance on the Bead Retrieval Task [Time taken: R^2 change: $F(6,23) = 0.19$, *ns*, $ES = 0.15$; Total score R^2 change: $F(6,23) = 0.48$, *ns*, $ES = 0.24$]. This held true even when intelligence was not accounted for.

Purdue Pegboard. After controlling for age and intelligence, performance on the executive function tasks did not significantly predict any condition of the Purdue Pegboard or the calculated “Purdue Pegboard Predicted Transfer Score.” This held true even when intelligence was not accounted for.

Table 11. Correlation between the Children's Learning Questionnaire and other measures, separated by group.

Measure	Pearson's Correlation	
	<i>FASD</i>	<i>Control</i>
<i>Transfer of Learning Measures</i>		
Tower of Hanoi - Learning Task	-0.53*	0.48
Tower of Hanoi - Transfer Task	-0.30	0.20
Bead Retrieval Task - Time Taken	0.31	0.51*
Bead Retrieval Task - Score	--	-0.39
Purdue Pegboard - Dominant Hand	-0.17	0.37
Purdue Pegboard - NonDominant Hand	-0.22	0.40
Purdue Pegboard - Both Hands	-0.19	0.23
Purdue Pegboard - Assemblies	-0.08	0.22
<i>Executive Function Measures</i>		
Picture Concepts - Total Score	0.09	-0.13
Stroop - Inhibition Ratio	0.14	-0.03
Stroop - Inhibition Errors	-0.04	-0.07
Stroop - Flexibility Ratio	0.17	0.20
Stroop - Flexibility Errors	-0.51*	0.08
Visual-Verbal Test - Total Misses	0.03	-0.01
<i>Adaptive Functioning Questionnaire</i>		
ABAS - Communication	-0.02	0.41
ABAS - Community Use	-0.23	0.15
ABAS - Functional Academics	-0.16	0.32
ABAS - Home Living	-0.34	-0.01
ABAS - Health & Safety	-0.31	0.36
ABAS - Leisure	-0.04	0.32
ABAS - Self-Care	-0.45	0.01
ABAS - Self-Direction	-0.42	0.23
ABAS - Social Skills	-0.48	0.61*

* $p < 0.05$

Discussion

This exploratory dissertation investigated transfer of learning abilities in children with FASD and in control children matched by age and gender. Participants completed three experimental transfer tasks, while parents or caregivers completed a questionnaire designed to measure transfer of learning in everyday life. In addition, two aspects of executive functioning were measured: concept formation and cognitive flexibility. This was undertaken to determine whether transfer of learning was related to executive functioning, because research has suggested that executive skills play an important role in promoting successful transfer. It was hypothesized that children with FASD would demonstrate weaker performance on all transfer and executive functioning measures, and that transfer of learning performance would relate significantly to executive functioning performance.

Transfer of Learning Measures

As hypothesized, children with FASD demonstrated weaker performance on the Transfer Condition of the Tower of Hanoi. They took significantly more trials to reach criterion than did control children, resulting in fewer earned points. This occurred only on the final two Tower of Hanoi transfer problems; the groups did not differ reliably on the first problem. The “Tower of Hanoi Predicted Transfer Score” sheds further light on children’s performance. This calculated variable represented children’s predicted transfer performance based on their earlier learning performance. Analyses with this variable suggested that even after taking into consideration their performance on the

Learning Condition, children with FASD performed significantly below control children on the Transfer Condition of the Tower of Hanoi. Additional analyses of total scores on both versions of the Tower of Hanoi suggested that control children performed very similarly between the two versions of the Tower of Hanoi. Indeed, they performed near ceiling levels on the Transfer Condition. These findings, in combination with the spontaneous verbal remarks made by most of the control children, suggest that they readily recognized the two versions as being essentially identical and were able to deploy the same strategies learned minutes earlier. By comparison, children with FASD showed weaker performance on the Transfer Condition of the Tower of Hanoi, even relative to their own performance on the first task. Despite having mastered the Learning Condition a few minutes earlier, they had significant difficulty executing identical strategies on the Transfer Condition and took more trials than control children to reach criterion. This was most pronounced on the third and most complex problem.

Observationally, only 2-3 children with FASD made spontaneous verbal remarks to the effect that they were engaged in a task that was almost identical to one completed earlier. This may be interpreted cautiously as additional evidence of weaker transfer of learning. To be fair, however, it is clear that children with FASD evidenced *some* transfer of learning on the second version of the Tower of Hanoi. Without further explanation, all children grasped that the transfer task involved placing containers inside of other containers, as per the Learning Condition. Likewise, they appeared to understand that the transfer task involved start states and working toward goal states in the right-most position of the task. They were also attuned to the rule that each problem

had to be accomplished in a specified number of moves, and were aware of when they reached the goal state having made too many moves.

As with many of the studies that have measured transfer of learning in general, a limitation of this dissertation is that weaker performance on the Tower of Hanoi Transfer Condition could reflect weak learning, weak memory, or some combination of the two. Several considerations suggest that these influences are likely to be minimal in this dissertation. First, after controlling for intelligence, the groups did not differ significantly in how quickly they reached criterion on the learning problems. Without controlling for intelligence, control children reached criterion in significantly fewer trials only on the second and third Tower of Hanoi learning problems. On average, children with FASD took only 1.25 more trials to reach criterion on learning problem 2, and 1.68 more trials to reach criterion on learning problem 3. In other words, the learning performance between the groups was not different to the extent that children with FASD demonstrated a questionable ability to learn the task. With respect to memory, the Tower of Hanoi procedure was designed to minimize poor transfer of learning secondary to questionable memory performance. This was accomplished through four main procedures: (1) reducing memory load with only three Tower of Hanoi problems; (2) reducing memory load by tailoring the complexity of the problems to children's age; (3) reducing memory load by administering the Transfer Condition immediately after the Learning Condition; and (4) ensuring successful encoding by providing children with demonstrations, strategies, and ample practice. According to the research reviewed earlier, children with FASD typically display adequate long-term retention of information

that is commensurate with initial acquisition. In other words, what they manage to encode, they manage to keep. Further, although children were provided with specific strategies to complete the task, the Tower of Hanoi requires manipulating objects and thus relies in part on procedural memory. This form of memory is robust relative to explicit memory, not only in FASD, but in other conditions that affect brain functioning. For example, Olson et al. (1998) found that alcohol-exposed children did not differ from controls when learning to press computer keys in a particular sequence, demonstrating intact procedural memory. When asked to verbally recall the sequence, however, they performed well below controls, demonstrating weaker declarative memory. Based on these considerations, the procedures used during the Tower of Hanoi were likely sufficient to minimize memory effects.

Unexpectedly and contrary to what was hypothesized, children with FASD did not have difficulty on the Bead Retrieval Problem. Several reasons, alone or in combination, may account for this finding. One possibility is that the transfer distance was too close between the source and target stories. In both stories, the protagonists were girls of about the same age, both girls were playing with groups of children, and both girls lost an object that they “could not reach.” Further, the source story explicitly furnished a strategy to retrieve the ping-pong ball, which was reinforced through pictures. These considerations are consistent with Chen’s (1996) research. He observed that overlapping superficial and structural similarities between source and target stories facilitated problem solving. He also noted that procedural similarity between the source and target problems facilitated transfer. That is, children benefited from “specific

operational features” in source stories that could be applied directly in target stories. In this dissertation, the similarity between the source and target stories may have reduced the transfer distance to the extent that relatively little transfer of learning was necessary to solve the problem.

This possibility is consistent with a case study by Padgett, Strickland, and Coles (2006). These authors created a virtual reality environment to measure the generalization of fire safety skills taught to five children with FASD. In the initial learning phase, children were taught how to sequence three cards depicting home fire safety steps. Next, they were taught three fire safety steps in the virtual reality environment. During the generalization phase, children were asked to respond to a simulated fire in the building. Padgett and colleagues found that all five children were able to learn both tasks, and demonstrated successful generalization by performing the fire safety steps correctly during the real-world simulation. Moreover, they could perform the steps correctly after one week. In the context of this dissertation, Padgett and colleagues’ procedure, and the Bead Retrieval Problem, could be considered “application transfer” according to Haskell (2001). Haskell suggested that the application of learning is not equivalent to the transfer of learning.

Another possibility is that there were not enough objects available for children to work with, so that sooner or later they would encounter the water container by chance or through a process of elimination. The average number of items used to retrieve the bead (which includes water) helps to refute this possibility. Out of six available items, children with FASD used 2.19 and control children 2.50, suggesting that both groups of

children tended to use the water before attempting other retrieval strategies. In addition, the number of solution-irrelevant objects in this task (five) is similar to the number of objects in Chen's (1996) study (seven). Moreover, the objects in this dissertation were selected because they had the appearance of being potentially useful in retrieving the bead. By comparison, Chen (1996) selected several distractor objects that appear to have less saliency as a means to retrieve the bead (e.g., index cards, a scarf, a wooden brick). Collectively, these considerations argue that there were likely an appropriate number of objects used in this dissertation.

A third possibility is that the size of the water container "pulled" for a response. Relative to the other items available in the task (e.g., scissors, a roll of string, paper clips), the water container was quite large and stood out. Many children also expressed surprise and delight (this task was a highlight of the study) at finding themselves in the company of a squeezable container that *actually* was filled with water. They gravitated toward it, and having done so, there was only one thing in sight that could accept water: a plastic tube with a wooden bead at the bottom.

Also contrary to what was hypothesized, children with FASD and control children did not differ significantly on any condition of the Purdue Pegboard after controlling for intelligence, nor on the calculated Purdue Pegboard Predicted Transfer Score. Interestingly, in the study by Roebuck and colleagues (2004), the authors attributed weaker bimanual coordination in the FASD group partly to weak problem solving, which was evident when children with FASD did not adjust their approach to the task as it became more complex. This finding is roughly analogous to the results of this

dissertation, where intelligence accounted for significant variability in the Assembly condition of the Purdue Pegboard. In both studies, however, one must consider that bimanual coordination typically requires well developed fine-motor dexterity, and this is an area known to be poorly developed in FASD (Mattson & Riley, 1998). In addition, because the Assembly condition is unique and complex compared to the first three conditions of the Purdue Pegboard, it likely requires new learning rather than transfer of learning and thus may be more influenced by intelligence.

In light of children's performance on the Tower of Hanoi and Bead Retrieval Problem, perhaps the results of the Purdue Pegboard are not surprising. As noted earlier, bimanual coordination may be considered to rely on low-level transfer of learning. According to Haskell's (2001) conceptualization of transfer, the Purdue Pegboard would likely involve Level 1 transfer of procedural-to-procedural knowledge, and based on the other transfer results of this dissertation, and on the results from Padgett et al. (2006), this level of transfer appears to be well within the capability of children with FASD.

Considering all of the transfer tasks as a whole, the results of this dissertation suggest that children with FASD demonstrated weak transfer of learning only when the transfer distance was sufficiently far, and when the transfer and learning tasks differed superficially but not structurally (i.e., when they "looked different"). These findings are consistent with what has been reported in the transfer literature. As noted, surface details of a problem are often irrelevant to its solution, yet surface details are often highly salient and can be misleading to those unfamiliar with a particular domain or to those generally less skilled in transfer of learning (Bassok, 2002). Skilled transfer often involves seeing

beyond surface details and understanding deeper, fundamental principles of a problem (Coley & Shafto, 2003; Goldstone & Sakamoto, 2002). In the context of this dissertation, children with FASD may have had difficulty on the Transfer Condition of the Tower of Hanoi because it *looked* very different from the Learning Condition, even though the two versions were structurally identical. Perhaps, being less skilled at transfer of learning, children with FASD were less able to see beyond the superficial differences between the two versions, and therefore less able to grasp that they were structurally identical. By comparison, the two stories of the Bead Retrieval Problem featured substantial surface and structural overlap, along with specific operational features that, together, likely required much less transfer of learning to reach a solution. Similarly, by design the Purdue Pegboard requires relatively low level transfer of mainly procedural-to-procedural information.

Parental Ratings of Transfer of Learning

On the new CLQ, parent reports of transfer abilities in everyday life also revealed significant perceived transfer deficits in FASD. A remarkable finding was that there was no overlap between the distribution of questionnaire scores. This likely suggests that the questionnaire captured various learning characteristics and behaviours of children with FASD that parents perceived as notably impaired in this population. It should be emphasized that parents were not informed that the questionnaire was designed to measure how well children with FASD can “generalize” information. This precaution was taken because the word “generalize” is a familiar and potentially loaded term in

those familiar with FASD; therefore, its use was eliminated from the questionnaire to reduce a negative response bias.

Several of the correlations between the CLQ and other measures in the study are worthy of comment (see Table 9). In children with FASD, CLQ scores correlated negatively and significantly with the Learning Condition of the Tower of Hanoi, and negatively (but not significantly) with the Transfer Condition. This finding runs counter to what was expected, and suggests that stronger parental reports of transfer ability was associated with weaker experimental transfer ability on the Tower of Hanoi. In control children, by comparison, this relationship fell in the expected direction; stronger parental reports of transfer ability was associated with better performance on the Tower of Hanoi. Although statistical significance was not reached in this relationship, this is most likely attributable to the small sample size. In control children, CLQ scores also were found to correlate significantly with the amount of time taken to complete the Bead Retrieval Problem. This finding should be interpreted cautiously, however, because of the three outlying control children who took a long time to complete the Bead Retrieval Problem.

When the results of the transfer tasks and the CLQ are considered as a whole, it is clear that the pattern of findings calls into question the construct validity of one or more measures. That is, if the CLQ and the transfer tasks were measuring identical constructs, one would expect these measures to be interrelated. This was not the case, and in fact some of the relationships ran counter to what was expected. One possible explanation for this finding is that the CLQ and the transfer tasks measured different kinds of transfer (e.g., Haskell, 2001). Another possibility is that the transfer tasks provided a “snapshot”

of children's ability to perform an action in a testing situation, whereas the CLQ probed for parental views of transfer ability in everyday life, which presumably was based on much more knowledge of and time spent with the child. A final possibility, of course, is that the transfer tasks and the CLQ fundamentally measured different constructs, or that one or more of the transfer tasks, or the CLQ, did not measure transfer of learning at all. Further research is required into the use of these instruments to assess transfer of learning.

Adaptive Functioning

Children with FASD also were rated as having significantly weaker adaptive functioning skills on all nine subscales of the ABAS-II before controlling for intelligence. Broadly speaking, these findings are consistent with other studies that have found adaptive impairments in those with FASD (Streissguth, 1997; Streissguth et al., 1991; Streissguth et al., 1997; Thomas et al., 1998). After controlling for intelligence, however, group differences remained on only four subscales. This pattern of results fits with current conceptualizations of adaptive functioning, which have distinguished two major categories of functional abilities. The first is *activities of daily living*, which comprise overlearned self-care activities such as dressing, feeding, bathing, toileting, and functional mobility. The second is *instrumental activities of daily living* and comprise activities such as taking care of people and pets, community mobility, shopping, managing one's health, finances, and household duties, engaging in leisure activities, and social participation (Youngstrom et al., 2002). Instrumental activities of daily living are

oriented toward interacting with the environment and are thought to require fairly complex cognitive processing (Youngstrom et al., 2002). This distinction surfaced prominently in the current ABAS-II results after controlling for intelligence. Children with FASD were rated as more impaired on instrumental adaptive skills (e.g., communication, health and safety, leisure, and social skills) but not on more basic ones (e.g., home living, self-care, self-direction, functional academics). An exception occurred on the *Community Use* subscale of the ABAS-II, which can be thought of as an instrumental activity of daily living according to Youngstrom and colleagues. At the young age of participants of this study, however, there would be few community use expectations. The current dissertation results are also consistent with those from Streissguth and colleagues (1996), who found that relatively complex adaptive skills were impaired in FASD, whereas basic daily living skills were not.

The robust group differences in leisure and social skills according to the ABAS-II are also consistent with research by Thomas et al. (1998). To investigate whether low intelligence was a primary factor contributing to social skills deficits, these authors compared children with FAS with two groups of control children on the social skills domain of the Vineland Adaptive Behaviour Scales. One group of control children was matched to the FAS group on the basis of verbal IQ. The other control group consisted of typically developing children with average to above-average intelligence. The authors found that children with FAS were significantly more impaired in their interpersonal relationship skills than were children in the VIQ-matched control group, and concluded that social deficits in children with FAS go beyond what can be explained by low IQ.

A similar pattern has been found in children with other disorders. In children with autism, for example, both cognitive and adaptive deficits have been found (Freeman, Ritvo, Yokota, Childs, & Pollard, 1988). Research into the relationship between these variables has shown that adaptive functioning in autism is often more impaired than are intellectual abilities (Freeman et al., 1991). It also has been noted that cognitive functioning is unrelated to the number of maladaptive behaviors reported by parents of children with autism (Freeman et al., 1991). In those with Asperger's Syndrome, the results of several studies have documented very weak socialization and daily living skills in the context of normal-range cognitive functioning (Szatmari, Archer, Fisman, Streiner, & Wilson, 1995). As an aside, transfer of learning has also been investigated in children with autism. Many studies in this area have investigated children's ability to learn and then generalize specific skills such as social skills (Hall & Smith, 1996), appropriate displays of affective behaviour (Gena, Krantz, McClannahan, & Pulson, 1996), and verbal responses to common questions (Handleman, 1979). The results of such studies are highly variable, but do suggest that transfer of learning is possible for this population in the context of appropriately tailored interventions, ample support, repetition, and environmental modifications that promote transfer.

Based on the transfer literature reviewed above, it is reasonable to speculate that weak transfer abilities could adversely affect adaptive functioning. This speculation is based on the "adaptive" component of adaptive functioning, which by definition implies modifying one's behaviour to accommodate the situation at hand. One cannot possibly prepare for every situation that comes along in a rapidly changing world; as such, most

problems in life will be new and unfamiliar. Therefore, adaptive functioning likely depends heavily on transfer of learning by adapting existing knowledge to the novel situation at hand. This suggestion remains to be tested experimentally.

Executive Functioning Tasks

When all of the executive functioning tasks were considered as a whole, control children demonstrated stronger performance, even while controlling for intelligence. This is consistent with the hypotheses of the dissertation, and also with other studies that have found executive impairments in FASD. More specific analyses, however, revealed differential findings among the tasks.

On Picture Concepts, reliable group differences were not found after controlling for intelligence. When intelligence was not controlled, children in the control group outperformed those with FASD. This finding is likely attributable to the fact that Picture Concepts is part of the WISC-IV, which is the same test battery from which Vocabulary and Matrix Reasoning were selected as measures of intelligence. Because these three subtests are correlated, statistically controlling for intelligence using Vocabulary and Matrix Reasoning removes variance shared with Picture Concepts, thereby statistically removing group differences on this measure. Certainly, this same principle applies to other measures in this dissertation. This important issue is discussed in more detail later.

With respect to the measures of flexibility, control children demonstrated faster relative performance on the flexibility condition of the Color-Word Interference Test while controlling for intelligence. This finding is consistent with the dissertation

hypotheses. The “relative” context is an important distinction, because it reflects children’s performance on the flexibility condition after taking account their performance on the initial control conditions of this task. Thus, not only did control children perform the task more quickly on average, but their speed did not decline on the flexibility condition as much as it did for children with FASD. This suggests that the flexibility condition “cost” children with FASD more than it cost control children; children with FASD could not switch back and forth between the different task requirements as efficiently as could control children.

By comparison, after controlling for intelligence, the groups did not differ reliably on the relative time taken to complete the inhibition condition, or in terms of the number of errors made on either condition. Likewise, group differences were not found on the Visual-Verbal Test after accounting for intelligence. Yet, when intelligence was not taken into consideration, control children demonstrated much better performance on all of these measures.

Considering all of the executive functioning tasks as a whole, then, control children demonstrated stronger performance overall, but much of the variability between the groups was attributable primarily but not exclusively to differences in intelligence. These results are reasonably consistent with those from the studies reviewed above, in which executive functioning has been investigated in FASD. To various extents, intelligence appears to play a moderating role (Connor et al., 2000; Kerns et al., 1997).

Additional analyses were also conducted to investigate whether transfer of learning relates to executive functioning. Whether or not intelligence was controlled, no

reliable relationship was observed between executive functioning and two of the transfer tasks, the Bead Retrieval Problem and the Purdue Pegboard. On the Tower of Hanoi, however, transfer abilities were related significantly to executive functioning abilities, but only when ignoring intelligence. In light of the prominent role that intelligence played in many of the tasks in this dissertation, it is not surprising that intelligence accounted for significant variance in the relationship between these two abilities.

When ignoring the effects of intelligence, a closer examination of the relationship between transfer of learning and executive functioning revealed that the relationship was driven primarily by cognitive flexibility. Children less skilled on the Tower of Hanoi were less able to identify alternative methods of grouping stimuli on the Visual-Verbal Test. It is interesting that flexibility as measured by the Visual-Verbal Test was predictive of Tower of Hanoi performance, whereas flexibility as measured by the Color-Word Interference Test was not. This provides support for the suggestion made by Eslinger and Grattan (1993) that there are different kinds of flexibility. The Visual-Verbal Test may be a higher-order measure of cognitive flexibility, similar to Eslinger and Grattan's "spontaneous flexibility," in that it requires verbal reasoning and response generation. The Color-Word Interference Test, in contrast, may tap an ability such as "response flexibility," akin to Eslinger and Grattan's "reactive flexibility," in that children must flexibly switch back and forth between naming the dissonant ink colour and reading the actual words. This task likely also required working memory to hold in mind which particular response to carry out in the moment - naming the ink colour, or reading the word.

The distinction between different kinds of flexibility also resembles the work of Casey and colleagues (Casey, Castellanos, Xavier, Giedd, Marsh, & Wendy, et al., 1997), who proposed that inhibitory control occurs through three stages of attentional processing, one at the sensory level (sensory selection) and two at the response level (response selection and response execution). In the same way, perhaps there are similar levels of flexibility, only some of which are related to transfer of learning. Whether or not this is the case, the current findings provide partial support for the hypothesis that transfer of learning is related to executive functioning. However, this relationship was confined only to flexibility, and was moderated significantly by intelligence.

The Effects of Intelligence

A prominent finding in this dissertation was that group differences in intelligence accounted for significant variability between the two groups of children. The issue of whether intelligence should be statistically controlled has not been fully resolved in the literature. In part this is because ANCOVA is a controversial procedure and subject to misuse (Adams, Brown, & Grant, 1985; Pedhazur, 1997). Pedhazur (1997) noted that ANCOVA can be used for two different purposes: (1) statistical control of variables that are not part of the model; and (2) adjustment for initial differences among groups being compared. Only the first application is justifiable, whereas the second is “fraught with serious flaws” (Pedhazur, 1997).

Mathematically, ANCOVA uses techniques common to both ANOVA and multiple regression. It is equivalent to performing an ANOVA on the residualized

variable from which the covariate has been partialled out through regression. As such, ANCOVA includes the same assumptions as ANOVA, along with two additional assumptions regarding the relationship between the covariate and the dependent variable. The first assumption is that the covariances between the covariate and the dependent variable, within each group, do not differ significantly from one another. In other words, the relationship (or slope of the regression equation) between the covariate and the dependent variable in one group of participants is similar to that in another group of participants. This assumption is termed the homogeneity of regressions (Pedhazur, 1997). In this dissertation, this assumption would concern the relationship between intelligence (covariate) and the dependent variable of interest (e.g., Tower of Hanoi performance) in the two groups of children. It stipulates that for each group of children, the slope of the regression line, when regressing Tower of Hanoi performance onto intelligence, is equivalent. The second assumption in ANCOVA is that the relationship between the covariate and the dependent variable is linear (versus cubic or quadratic; Pedhazur, 1997). For example, this assumption stipulates that the relationship between intelligence and Tower of Hanoi performance is best described by a straight line, and that the value of one does not change disproportionately across levels of the other.

A potential misuse of ANCOVA occurs when it is used to adjust for initial differences between groups. The danger is that the dependent variable (e.g., Tower of Hanoi performance) may be affected by the covariate, in which case partialing out the effects of the covariate removes some of the effects of the dependent variable (Pedhazur, 1997). Adams et al. (1985) enjoined readers to consider the psychological relationships

between the covariate and the dependent variable, rather than simply trying to “control for” the covariate. They cautioned that it is wrong to assume that by statistically controlling for the covariate, one has magically removed the effects of the covariate from the dependent variable. In the same vein, they noted that correcting for demographic variables is especially insidious because doing so may unwittingly remove the effects of other variables that impact the dependent variable. For example, by statistically controlling for age, one may unwittingly correct for educational experience, opportunity, SES, and other influences. It then would be wrong to conclude that by controlling for the covariate, you have eliminated it as an alternative explanation for group differences.

Nevertheless, this potential misuse of ANCOVA has been espoused by several authors. For example, Lahey, Pelham, Stein, Loney, Trapani, Nugent, et al (1998) suggested controlling for intelligence and other moderating variables so that neuropsychological impairments found in a disorder cannot be explained more parsimoniously by these variables. Other researchers have suggested an opposite approach, that neuropsychological impairments in a disorder may directly *cause* group differences in variables such as intelligence. Thus, statistically controlling for these variables removes shared variance and weakens group differences (Barkley, 1997). For the purpose of this dissertation, the current results were cast both before and after controlling for intelligence to demonstrate the effects of accounting for this variable.

In this dissertation, intelligence is known to be related to learning, which in turn is related to transfer of learning (Coley et al., 2004; Galotti, 1989; Haskell, 2001). Thus, statistically controlling for group differences in intelligence has the unwanted side effect

of accounting for variability in transfer of learning - the variable of interest - thereby reducing or eliminating group differences on this variable. This was the case for many other variables in this dissertation, including the measures of executive functioning, which others have found vary with intelligence (Connor et al., 2000; Kerns et al., 1997).

For this dissertation, a case can be made for investigating transfer of learning deficits *beyond* those accounted for by intelligence because it is well established that FASD is associated with lower intelligence and mental retardation (Stratton et al., 1996). We expect those with lower intelligence to do less well on most activities. Therefore, in the context of a disorder such as FASD, weakness in a particular area that can be accounted for by something beyond intelligence is more likely to be a *core deficit* of the disorder (Dennis, 2000). Core deficits are cognitive impairments that are “robust across various levels of disorder severity and mental ability” (Dennis, 2000). In other words, cognitive deficits that persist in groups of higher intelligence are more likely to be core deficits. By comparison, cognitive impairments that vary with intelligence are less likely to be specific to a disorder, and instead may stem from more general cognitive processing limitations (Dennis, 2000).

The reported pervasiveness of poor generalization abilities in FASD, even in those with average-range intelligence, suggests that this characteristic may be a core deficit of the disorder. The results of this dissertation partially support this possibility, in that transfer deficits on the Tower of Hanoi persisted even after controlling for intelligence. This makes the transfer deficit more compelling, and fits with the anecdotal evidence that even children with FASD who have average-range intelligence tend to have

difficulty generalizing information. This finding is even more salient given both the small sample size and the loss of statistical power that occurs in covariance analysis.

Clinical Implications

“Teach for transfer” is the chief clinical implication of this dissertation. Children with FASD appeared to have transfer difficulties when tasks had the same structure, but looked different. In contrast, they appeared to perform comparable to control children when tasks looked the same and had the same structure. This may help explain why, for example, a child with FASD can solve an addition problem involving two apples, but has trouble solving an addition problem that involves two books. Or why a child with FASD may learn not to play on the road outside of his or her house, yet play on the road around the corner. In both examples, the structure is the same, but the surface details are different. The child may be thrown off by appearances.

In everyday life, children with FASD would likely benefit from strategies that promote transfer of learning through environmental modifications, learning modifications, self-regulation strategies, or all three. These principles are summarized in Table 12. An example of an environmental modification is to make new learning situations similar to well-learned situations in terms of surface and structural features. For example, if the learning goal involves entering a classroom, sitting down at a desk, and remaining seated and quiet until the teacher begins a lesson, environmental modifications could include keeping the child’s desk location relatively consistent among

classes (e.g., nearest the teacher) and consistently using a “be seated and be quiet” signal that all teachers use with that child.

When this level of structure and consistency is not possible, learning modifications may be necessary. For example, knowing that a new situation is likely to be sufficiently different from one encountered before, those with FASD may need to be explicitly taught desired behaviours in the new situation. This recommendation is very much in line with Detterman’s (1993) view, who contended that learning does not transfer to novel situations, and therefore suggests that education should focus on teaching the precise knowledge that will be needed later. In those with FASD, or in others with particularly weak transfer abilities, desired behaviours may have to be taught in all required settings, which effectively assumes that transfer of learning will not take place. Either way, given Haskell’s (2001) view that all learning involves transfer, those with FASD would likely benefit from being provided with explicit links between new learning and prior learning to “bridge the transfer gap.” For example, the same child from the classroom, who now finds himself expected to remain seated and quiet in a theatre or library, may benefit from being taught how the two settings are similar, and may respond to the same “be seated and be quiet” cue used in the classroom.

Realistically, however, this level of support cannot be provided throughout life.

Therefore, teaching those with FASD self-monitoring and problem solving strategies may be helpful so that, ultimately, he or she can develop the skills necessary to handle novelty.

Regardless of the strategy or treatment principle that is applied, structure, consistency, and repetition will be necessary. Those with FASD will likely need ample opportunities for practice. Other research suggests that learning can be facilitated by presenting information in multiple modalities and by capturing children's interest using enjoyable learning methods (e.g., Padgett et al., 2006).

Table 12. Strategies to promote transfer of learning.

Environmental/Contextual Modifications

Make new situations similar to well-learned situations in terms of surface and structural features.

Learning Modifications

Teach desired behaviours in required settings.

Since all learning involves transfer (Haskell, 2001), make explicit links between new learning and prior learning to "bridge the transfer gap" for children with FASD. Relate new information to what the child already knows well.

Explicitly teach the child how two situations are alike, along with what actions or behaviours should be carried out now.

Self-Regulation Strategies

Teach child to reflect on and identify how two situations are alike, and what kind of past action or behaviour would be appropriate now.

Directions for Future Research

Although this dissertation was exploratory in nature, the results were encouraging and provide partial support for the anecdotal evidence and clinical lore that children with FASD have difficulty generalizing information. Because this is the first known study of

transfer of learning in FASD, there are many opportunities for future research. For example, the current results are polarized in that children with FASD demonstrated clear performance difficulties (Tower of Hanoi) or they did not (Bead Retrieval Problem and Purdue Pegboard). Further research into the shades of transfer difficulties and into the details of what makes transfer of learning difficult for this population would not only be interesting, but could have tremendous clinical potential. For example, do individuals with FASD have transfer difficulties only beyond a certain level of transfer, and if so, what is that level? If those with FASD really are thrown off by surface details, would they show better transfer when told explicitly that the structure is the same (e.g., on the Tower of Hanoi: “Just do what you did on the last task.”)? Would those with FASD show better transfer of learning with one “kind” of transfer over another (e.g., declarative-to-procedural vs. procedural-to-declarative; literal vs. lateral; see Table 2 for more examples)?

One’s knowledge base and familiarity with a particular domain also have been identified as important variables for transfer of learning. It would be enlightening to investigate these variables in FASD. For example, would those with FASD show age-appropriate transfer performance in areas with which they are very familiar? Could weak transfer abilities in FASD exist because these individuals tend to have a limited knowledge base secondary to cognitive, learning, and academic difficulties?

Further research into the relationship between transfer of learning and executive functioning also would be worthwhile. In a very recent study, Richland and colleagues (2006) proposed that analogical reasoning depends both on working memory and

inhibitory control. They suggested that working memory is important because analogical reasoning requires representing in working memory source and target analogs, and mapping elements of each analog based on correspondences between them. As working memory capacity increases throughout development, so does the capacity to handle increased relational complexity, and hence a greater capacity for analogical reasoning (Richland et al., 2006). These authors proposed that inhibitory control also is important for analogical reasoning because it allows one to respond less on the basis of salient superficial similarities between situations, and more on the basis of relational correspondences (Richland et al., 2006). In light of these views, research aimed specifically at the relationships among transfer of learning, working memory, and inhibition may be a fruitful area of exploration.

Finally, the results of the new CLQ were highly encouraging. Clearly, as a new clinical instrument, this questionnaire needs examination of statistical properties such as validity and reliability. Although the groups yielded two distinct distributions of scores, it is unclear whether the findings are *specific* to FASD, or whether the questionnaire simply provided a nonspecific indication of pathology. Administering the questionnaire to other clinical populations (e.g., children with ADHD) would help address this question, and would shed light on whether the CLQ indeed relates to a child's skills in transfer of learning.

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Appendix A: Correlations Among Transfer Tasks and the ABAS-II in Control Children

Appendix A: Correlations among the Transfer of Learning tasks and ABAS-II subscales in control children

	ToH Learning Condition	ToH Transfer Condition	ToH PTS	BRP Time	BRP Items	Purdue Pegboard PTS	Communication	Community Use	Functional Academics	Home Living	Health & Safety	Leisure	Self-Care	Self-Direction	Social Skills
ToH Learning Condition	--														
ToH Transfer Condition	0.20	--													
ToH PTS	-0.42	0.80**	--												
BRP Time	0.35	0.36	0.13	--											
BRP Items	0.31	0.12	-0.07	0.81**	--										
Purdue Pegboard PTS	-0.18	0.07	0.18	-0.02	0.11	--									
ABAS-II Communication	0.30	0.02	-0.17	0.08	0.10	-0.33	--								
ABAS-II Community Use	-0.04	0.30	0.30	0.19	0.08	-0.13	0.49	--							
ABAS-II Functional Academics	-0.16	-0.06	0.05	0.16	0.20	-0.14	0.71**	0.70**	--						
ABAS-II Home Living	-0.32	0.02	0.21	0.00	-0.10	0.13	0.39	0.70**	0.72**	--					
ABAS-II Health & Safety	0.08	0.22	0.15	0.20	0.09	0.40	0.39	0.48	0.41	0.60*	--				
ABAS-II Leisure	0.19	-0.07	-0.18	-0.01	-0.11	-0.10	0.61*	0.26	0.43	0.57*	0.47	--			
ABAS-II Self-Care	-0.25	0.08	0.22	-0.10	-0.22	0.17	0.48	0.22	0.44	0.71**	0.59*	0.71**	--		
ABAS-II Self-Direction	-0.12	0.31	0.37	0.25	0.06	0.11	0.54*	0.24	0.54*	0.34	0.47	0.32	0.55*	--	
ABAS-II Social Skills	0.36	0.33	0.09	0.03	-0.14	-0.21	0.48	0.15	0.17	0.16	0.44	0.58*	0.43	0.32	--

Notes: ToH = Tower of Hanoi; PTS = Predicted Transfer Score; BRP = Bead Retrieval Problem; ABAS-II = Adaptive Behavior Assessment System, Second Edition
*p < 0.05; **p < 0.01

Appendix B: Correlations Among Transfer Tasks and the ABAS-II in Children With FASD

Appendix B: Correlations among the Transfer of Learning tasks and ABAS-II subscales in children with FASD

	ToH Learning Condition	ToH Transfer Condition	ToH PTS	BRP Time	BRP Items	Purdue Pegboard	PTS	ABAS-II Communication	ABAS-II Community Use	ABAS-II Functional Academics	ABAS-II Home Living	ABAS-II Health & Safety	ABAS-II Leisure	ABAS-II Self-Care	ABAS-II Self-Direction	ABAS-II Social Skills
ToH Learning Condition	--															
ToH Transfer Condition	0.28	--														
ToH PTS	-0.41	0.76**	--													
BRP Time	0.03	-0.08	-0.10	--												
BRP Items	0.04	0.11	0.08	0.75**	--											
Purdue Pegboard	0.41	0.17	-0.11	0.07	0.08	--										
ABAS-II Communication	-0.09	0.09	0.14	0.10	0.07	-0.27	--									
ABAS-II Community Use	0.30	-0.05	-0.25	0.40	0.26	-0.08	0.74**	--								
ABAS-II Functional Academics	0.09	0.31	0.23	0.40	0.35	0.10	0.49	0.57*	--							
ABAS-II Home Living	0.38	0.21	-0.05	0.29	0.15	-0.05	0.58*	0.80**	0.67**	--						
ABAS-II Health & Safety	0.04	0.19	0.15	0.05	0.04	-0.27	0.83**	0.70**	0.56*	0.79**	--					
ABAS-II Leisure	-0.21	0.16	0.30	0.23	0.11	-0.38	0.67**	0.59*	0.63**	0.74**	0.76**	--				
ABAS-II Self-Care	0.13	0.26	0.16	-0.24	-0.21	-0.24	0.69**	0.52*	0.46	0.64**	0.72**	0.70**	--			
ABAS-II Self-Direction	0.37	0.31	0.04	-0.04	-0.07	-0.28	0.64**	0.64**	0.41	0.77**	0.69**	0.71**	0.89**	--		
ABAS-II Social Skills	0.20	0.46	0.30	-0.31	-0.14	-0.24	0.72**	0.48	0.41	0.60*	0.78**	0.63**	0.89**	0.85**	--	

Notes: ToH = Tower of Hanoi; PTS = Predicted Transfer Score; BRP = Bead Retrieval Problem; ABAS-II = Adaptive Behavior Assessment System, Second Edition
*p < 0.05; **p < 0.01

Appendix C: Parental Consent Form

CONSENT FORM

Transfer of Learning in Children with Fetal Alcohol Spectrum Disorder (FASD)

You are invited to participate in a research study investigating transfer of learning difficulties in children with FASD. These difficulties are commonly reported by parents, guardians, and others who work with children with prenatal alcohol exposure. For example, it is often reported that children with FASD are able to learn something in one environment, but cannot apply the same learning in another environment. Although such difficulties are very common in those with FASD, they have not been well researched or quantified. We hope that this study will help us to better understand the nature of these difficulties, and ultimately to develop intervention or remediation strategies to promote the transfer of learning in individuals with FASD. The study will occur under the direction of **Robert McInerney**, a doctoral student in psychology, as part of the requirements for his Ph.D. The study will be supervised by Robert McInerney's graduate supervisor, **Dr. Kimberly Kerns**, who is an Associate Professor in psychology and a registered psychologist.

We are seeking children who have an existing diagnosis of FASD, along with children who do not have FASD. All children will complete a number of hands-on activities, such as playing with plastic cups and Tupperware containers, matching pictures, listening to stories, and defining words. Most children find these activities enjoyable and fun. As a parent or guardian, you will be asked to complete two questionnaires regarding your child's day-to-day behaviour and functioning at home. The study will occur at the University of Victoria and will take between 1.5 and 2 hours. Your child will be provided with breaks as needed throughout this period. There are **no known risks** associated with this study. As a token of our appreciation for participating, you and your child each will receive \$5.00.

We would like to emphasize that both your child's participation and your participation in this study are **completely voluntary**. Even after agreeing to participate in the study, you have the right to withdraw at any time without explanation, and without any negative consequences whatsoever. At your discretion, we will retain the data collected up to the point of withdrawal, or destroy all of it immediately. You also have the right to decline to participate in one or more particular parts of the study, while agreeing to participate in other parts (e.g., you may refuse to answer particular questions).

Your child's participation in this study, and all data collected, whether partial or complete, will remain **completely confidential**. Your child's participation in this study will not be revealed to anyone (e.g., as applicable: the physician who referred you to the study, parents at FASD support groups, your child's teacher). Further, all data (including questionnaire data) will be digitized using code numbers instead of your child's name, which means that after this process, all data will be **anonymous** (i.e., not even Robert McInerney will be able to associate your child's data with his or her identity). This digital data will be encrypted for added protection, and all of the paper from which the information was taken will be shredded immediately. Only Robert McInerney or Dr. Kimberly Kerns will have access to the data.

At the end of the study, it is expected that the results will be published in a scientific journal. These results will be presented “as a group,” which means there will be no data presented from any child as an individual. Further, because all data will be anonymous, it will be impossible to associate your child’s data with his or her identify. There will be no other uses of the data.

If you have any questions, comments, or concerns about any aspect of this study, **please do not hesitate to raise them now**. Alternatively, you may phone Robert McInerney at 472-4195, or Dr. Kimberly Kerns at 721-7553. You may also verify the ethical approval of this study, or raise any concerns you might have, by contacting the Associate Vice-President Research at (250) 472-4545 or ovprhe@uvic.ca.

Please take a copy of this consent form for your records. In addition, a copy will be retained by Robert McInerney.

Child’s Name: _____

Your Name: _____

Signatures: _____

Parent/guardian

Researcher

Date: _____

Appendix D: Children's Consent Form

CHILDREN'S CONSENT FORM

My name is _____.

Today I will be working with Robert McInerney at the University of Victoria. He is a student in psychology and would like me to play some special activities. For example, I will play with some plastic containers, I will hear some short stories, and I will point to pictures that are the same in some way. Playing these special activities will help people better understand how children learn. For coming in today, Robert will give me \$5.00.

I am here today because I decided I would like to do these special activities with Robert. If I change my mind and decide that I don't want to play any more, I just have to tell Robert and he will let me leave. My time here today, and all of my "data" (scores, numbers, and other information) about me will remain confidential - that means no one (except Robert or his teacher) will be able to know my name, or know that it was me who played. In fact, instead of using my real name, I will be given my own "secret code!"

If I have any questions, my parents or I can call Robert McInerney at 472-4195 or his teacher, Dr. Kimberly Kerns, at 721-7553.

My signature: _____

Date: _____

Appendix E: Bead Retrieval Problem

Bead Retrieval Problem

Source Story

- [Picture 1] Diane was eight years old.
- [Picture 2] One day she and her friends were playing outside and decided to play ping-pong.
- [Picture 3] However, one of her friends had thrown their only ping-pong ball into a rain barrel, and they could not reach it. Diane tried many times to reach it but could not.
- [Picture 4] Finally, she found a bucket of water.
- [Picture 5] Diane poured water into the rain barrel, and the ping-pong ball began to float.
- [Picture 6] Then Diane was able to reach the ball and begin playing ping-pong.

Content Questions

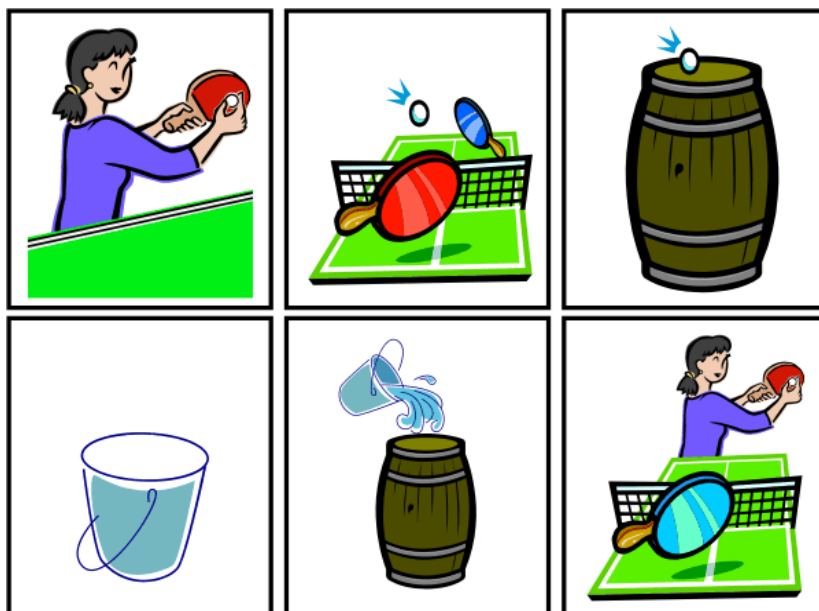
1. What did the children lose? 2. Where did they lose it? 3. How did they get it back?

Target Story

Jennifer was a seven-year-old girl. One day she was playing in the yard with some friends when they decided they wanted to play a different game. But one of her friends had dropped a bead into a tube, and they needed that bead to play their game. Jennifer could not reach the bead with her hands and she could not turn the tube upside down. So, she had to find another way to get the bead out. She found many things lying around that she could use.

Here is the tube and the bead, and many different things she could try to use. Can you show me how Jennifer could get the bead out? You can use any or all of the things here on the table to help you.

Story Cards



Appendix F: Transfer of Learning Questionnaire

Children's Behaviour Questionnaire

Child's name:	Birth date:	Age:
Grade:	Today's date:	
Your name:	Relationship to child:	

Please answer the following questions about your child by circling the appropriate number. Please answer all questions as honestly and thoroughly as possible, and do not skip items. *Thank you for your time and effort!*

My Child...

	Never	Rarely	Sometimes	Often
1. Is able to learn from the experience of other people (e.g., siblings, family, friends).	0	1	2	3
2. Can adapt knowledge or specific skills to handle new situations.	0	1	2	3
3. Is able to "learn by example."	0	1	2	3
4. Recognizes that some situation is one that he or she has seen before, and is able to behave now as he or she did then.	0	1	2	3
5. Gets confused or "thrown off" by small changes in details (e.g., character details in math problems).	0	1	2	3
6. Has difficulty understanding the deeper or more abstract similarities among similar situations.	0	1	2	3
7. Has trouble applying learned skills to current situations.	0	1	2	3
8. Can apply information learned at school in the "real world."	0	1	2	3
9. Can apply information learned in one situation to new, similar situations.	0	1	2	3
10. Is able to draw upon experience and knowledge to solve a problem.	0	1	2	3
11. Is able to generate unique ideas during "brainstorming" sessions with friends, family, or at school.	0	1	2	3
12. Is able to change a plan or develop alternatives if required.	0	1	2	3
13. Has trouble getting used to new situations (e.g., classes, groups, friends).	0	1	2	3
14. Has a broad knowledge base of general information.	0	1	2	3
15. Is able to learn by watching others ("modelling").	0	1	2	3
16. Can problem solve.	0	1	2	3
17. Is creative.	0	1	2	3
18. Resists changes in routine, food, places, etc.	0	1	2	3
19. Makes the same mistakes over and over.	0	1	2	3
20. Can think abstractly.	0	1	2	3
21. Learns from his or her own experiences.	0	1	2	3
22. Has trouble coming up with ideas for what to do in play or free time.	0	1	2	3