Memory functioning in children born with low birth weight: A comparison with normal birth weight children diagnosed with attention deficit hyperactivity disorder.

Tammy L. Whitlock
University of Windsor

Follow this and additional works at: https://scholar.uwindsor.ca/etd

Recommended Citation
https://scholar.uwindsor.ca/etd/2698
INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI®
MEMORY FUNCTIONING IN CHILDREN BORN WITH LOW BIRTH WEIGHT: A
COMPARISON WITH NORMAL BIRTH WEIGHT CHILDREN DIAGNOSED WITH
ATTENTION DEFICIT HYPERACTIVITY DISORDER

by
Tammy L. Whitlock
Hons. B.Sc. Carleton University, 2000

A Thesis
Submitted to the Faculty of Graduate Studies and Research
through the Department of Psychology
in Partial Fulfillment of the Requirements for
the Degree of Master of Arts at the
University of Windsor

Windsor, Ontario, Canada

2002

© 2002 Tammy L. Whitlock
The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-75856-7
ABSTRACT

Medical advances over the last two decades have lead to increased survival rates of children born with increasingly lower birth weights. Studies have revealed that the lower the birth weight of the child, the higher the possibility that he/she will develop some associated neurological and neuropsychological problems. Archival data for children used in this study were collected through a retrospective chart review at Henry Ford Hospital in Detroit, Michigan. The purpose of this study was to examine possible deficits in different aspects of memory, (visual, verbal, and delayed recall) in children born with LBW and to compare these deficits with children born with normal birth weight (NBW) who have been diagnosed with attention deficit hyperactivity disorder (ADHD). A total of 86 children between the ages of 5 and 13 were administered the Test of Memory and Learning (TOMAL) as a measure of memory functioning. Other neuropsychological measures administered were the Beery test of Visual Motor Integration (VMI), the Peabody Picture Vocabulary Test (PPVT), the Wisconsin Card Sorting Test (WCST), the visual and auditory attention subtests of the NEPSY, and the Wechsler Intelligence Scale for Children, 3rd edition (WISC-III) or the Stanford Binet Test of Intelligence as a measure of global intellectual functioning. Results revealed that children with LBW demonstrate below average performance on measures of nonverbal (NM) and sequential memory. Below average performance was also measured on the VMI, PPVT, WCST and NEPSY attention measures. When compared to children with ADHD, the children in the LBW group demonstrated significantly poorer performance in visual attention, delayed
recall, nonverbal, and sequential memory. In addition, only nonverbal memory scores were significantly and positively correlated with birth weight. However, variance in nonverbal memory scores was predicted primarily by IQ, PPVT, and NEPSY visual attention scores.
ACKNOWLEDGEMENTS

I would like to express my appreciation to all those who have encouraged, supported and guided me throughout my studies. First, I would like to thank my supervisor, Dr. Byron Rourke for contributing his knowledge and expertise to this project. Next, I would like to thank Dr. Renee Lajiness-O’Neill for her guidance and valuable suggestions. I would also like to extend my gratitude to her and the staff of the Neuropsychology Department at Henry Ford Hospital for generously allowing me to use data from the department for this project. In addition, I would like to acknowledge my committee members, Dr. Joseph Casey and Dr. Larry Morton for their comments and suggestions which have aided in the completion of this project. Finally, I would like to thank my friends, family, classmates, and especially my husband, for their ongoing encouragement and support throughout the years.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTERS</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Diagnosis and Severity</td>
<td>2</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>2</td>
</tr>
<tr>
<td>Risk Factors</td>
<td>3</td>
</tr>
<tr>
<td>Associated Medical Conditions</td>
<td>4</td>
</tr>
<tr>
<td>Neuropsychological Sequelae</td>
<td>8</td>
</tr>
<tr>
<td>Intelligence and Achievement Testing</td>
<td>9</td>
</tr>
<tr>
<td>Biological and Psychosocial Risk Factors associated with Neuropsychological Sequelae</td>
<td>11</td>
</tr>
<tr>
<td>Comorbidity</td>
<td>14</td>
</tr>
<tr>
<td>Visual System and Visual Spatial Abilities</td>
<td>16</td>
</tr>
<tr>
<td>Attention and Memory</td>
<td>17</td>
</tr>
<tr>
<td>Purpose and Hypotheses</td>
<td>20</td>
</tr>
<tr>
<td>II. METHOD</td>
<td></td>
</tr>
<tr>
<td>Participants</td>
<td>22</td>
</tr>
<tr>
<td>Testing Procedures</td>
<td>23</td>
</tr>
</tbody>
</table>
Data Analysis 24

III. RESULT 26

Hypothesis 1 26
Hypothesis 2 33
Hypothesis 3 35
Hypothesis 4 35
Hypothesis 5 44
Hypothesis 6 44
Hypothesis 7 50

IV. DISCUSSION 53

Study Limitation and Future Directions 60
Conclusions 61

REFERENCES 63

VITA AUCTORIS 68
List of Tables

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mean and standard deviation scores on for NBW/ADHD and LBW groups on all measures.</td>
<td>27</td>
</tr>
<tr>
<td>2. Pearson Correlation values for relationship between TOMAL scores and FSIQ, PPVT-III, VMI, WCST, and NEPSY scores for all subjects</td>
<td>31</td>
</tr>
<tr>
<td>3 Mean NEPSY and WCST standard scores for NBW/ADHD and LBW groups</td>
<td>42</td>
</tr>
<tr>
<td>4 Independent sample t-test scores for comparison of mean standard NEPSY and WSCT scores between LBW and NBW/ADHD groups</td>
<td>43</td>
</tr>
<tr>
<td>5 Mean scores for NBW/ADHD and LBW groups on TOMAL subtests</td>
<td>48</td>
</tr>
<tr>
<td>6 Independent sample t-test scores for comparison of mean standard TOMAL scores between LBW and NBW/ADHD groups</td>
<td>49</td>
</tr>
</tbody>
</table>
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Histogram of the distribution of the birth weights of all subjects</td>
<td>28</td>
</tr>
<tr>
<td>2. Histogram of the distribution of subjects in each birth weight category with 1.0 representing NBW, 2.0 representing LBW, 3.0 representing VLBW, and 4.0 representing ELBW</td>
<td>29</td>
</tr>
<tr>
<td>3. Distribution of VMI standard scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.</td>
<td>34</td>
</tr>
<tr>
<td>4. Distribution of PPVT standard scores both all subjects in the NBW/ADHD (above) and LBW (below) groups</td>
<td>36</td>
</tr>
<tr>
<td>5. Distribution of NEPSY auditory attention scaled scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.</td>
<td>38</td>
</tr>
<tr>
<td>6. Distribution of NEPSY visual attention scaled scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.</td>
<td>39</td>
</tr>
<tr>
<td>7. Distribution of WCST perseverative errors scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.</td>
<td>40</td>
</tr>
<tr>
<td>8. Distribution of WCST conceptual level response scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.</td>
<td>41</td>
</tr>
<tr>
<td>9. Distribution of TOMAL VM composite scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.</td>
<td>45</td>
</tr>
<tr>
<td>10. Distribution of TOMAL NM composite scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.</td>
<td>46</td>
</tr>
<tr>
<td>11. Distribution of TOMAL DRI scores for all subjects in NBW/ADHD (above) and LBW (below) groups.</td>
<td>46</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

The average newborn weighs over 2500 grams (g) at birth with a gestation period of 37 weeks or more (Spren, Riser, & Edgell, 1995). As determined by the World Health Organization (1963), children born weighing less than 2500 g are termed low birth weight (LBW). According to Picard, Del Dotto, and Breslau (2000), LBW accounts for 6.0 to 6.9% of all live births in the United States.

In the 1960s, the mortality rate for children who were born weighing less than 1500 g was approximately 75% (Spren et al., 1995). Improved methods of delivery and neonatal care, including the use of antenatal glucocorticoid therapy and the introduction of surfactant in the 1980s (Futagi, Suzuki, Goto, & Kato, 1999) have improved the survival rate of infants, with birth weights as low as 750 g or less. Currently, a number of medical treatments are being developed to help further increase the chances of survival of LBW infants (Watterberg et al., 1999; Hay et al., 1999).

As the chances of survival of children who are born weighing less than 750 g improve there are also unfortunate consequences. There is increasing evidence that these children born with extremely low birth weight (ELBW) are prone to developing many associated medical conditions and neuropsychological problems. Studies indicate that the lower the birth weight of the child, the higher the possibility that he/she will develop some associated neurological and neuropsychological problems (Picard et al., 2000; Taylor, Klein, Schatschneider, & Hack, 1998).
Diagnosis and Severity

In terms of diagnosis, there are four categories of birth weights, as defined by the World Health Organization (1963) that may determine the severity of the case. Infants weighing 2500 g or more at birth are considered to be of normal birth weight (NBW). Infants weighing between 2500 g and 1500 g at birth are termed LBW, whereas the cutoff between infants that are born with very low birth weight (VLBW) and infants born with ELBW is 1000 g (Martinez, Weiss, Partridge, Freeman, & Kilpatrick, 1998; Picard et al., 2000; Sreen et al., 1995).

There are two main events that lead to a child being under weight at birth. In North America, the first and most common reason is that the child is born before 37 weeks gestation but with a weight appropriate for their gestational age. The second cause of LBW is intrauterine growth retardation (IUGR), which occurs in children whose birth weight falls below the 10th percentile for gestational age. Infants with IUGR may be born early (before 37 weeks gestation) or at full term (Sreen et al., 1995).

Epidemiology

LBW (2500 g or less) is the most important determinant of neonatal mortality (death within the first 28 days of life). In 1980, LBW contributed to 71% of perinatal deaths and 42% of neonatal deaths in the United States (Jason & Jarris, 1987). It is assumed that improved medical practices and the introduction of surfactant and antenatal glucocorticoid administration have improved the survival rates of infants born with LBW. Almost 20 years after the study conducted by Jason and Jarris (1987), survival rates for infants born at 23 weeks gestation have been reported to range between 15% and 23% to
30% at 24 weeks gestation and almost 50% at 25 weeks gestation (Martinez et al., 1998).

Survival of neonates with ELBW increased, in the United States, from 20% to 59% in 1979 and 1994, respectively. No increases in the rate of major developmental problems identifiable at 1 year of age were reported between these times periods (O'Shea, Klinepeter, Goldstein, Jackson, & Dillard, 1997).

In the city of Detroit, 11% of newborns discharged from an urban hospital between 1983 and 1985 were born with birth weights less than 2500 g. During the same time period, 6.4% of infants discharged from a suburban hospital in Detroit area fit the criteria of LBW (Breslau et al., 1996a).

Risk Factors
Both prematurity and IUGR as causes for LBW are associated with different risk factors and are therefore thought to represent pathophysiologically different processes (Picard, et al., 2000). For instance, in developed countries and areas of higher socio-economic status, two-thirds of infants born with LBW are preterm. In contrast, IUGR is the primary cause of LBW in developing countries (Sreen et al., 1995).

Currently there are no known methods for the prevention of prematurity but many risk factors have been associated with prematurity and IUGR (Picard et al., 2000). Risk factors that have been found to specifically contribute to prematurity are mother's age, previous pregnancy history, cigarette smoking, weight gain during pregnancy, pre-pregnancy weight, birth order, family income, and education (Sreen et al., 1995). Specifically Sreen et al. (1995) report studies which indicate that there is an increased rate of premature births among women who are younger than 20 and older than 35 and in
Canada it has been shown that a previous preterm birth double the risk of having a LBW infant. This study also reports that income and education are inversely related to the likelihood of prematurity and that smoking during the second half of pregnancy has been associated with an average decrease of 200 g in birth weight.

The primary correlate of IUGR appears to be socio-economic status (Picard et al., 2000). Although not exclusively, this relationship is believed to be associated with an increased risk of malnutrition, poor medical conditions and increased exposure to toxins by mothers with lower socio-economic status. However, prematurity as a cause of LBW appears to be equally prevalent across ethnicity and gender (Picard et al., 2000).

Infants with LBW typically have births that are associated with pre- and perinatal complications. It has been reported that only 15 % of infants born weighing less than 750 g survive free of major medical complications (Martinez et al., 1999). These complications often lead to number medical conditions that are often associated with LBW and may lead to alterations in brain growth and development in these children (Landry, Fletcher, Denson, & Chapieski, 1993; Sreen et al., 1995; Picard et al., 2000).

**Associated Medical Conditions**

Two of the conditions often found in this population are hyaline membrane disease (HMD), which is also known as respiratory distress syndrome (RDS), and intraventricular or periventricular hemorrhage (IVH/PVH; Picard et al., 2000). These medical complications may be cause by pre- and perinatal factors such as inadequate oxygenation, in the case of RDS/HMD, or direct injury to the skull or brain in the case of PVH/IVH (Landry et al., 1993).
RDS/HMD is the result of immature lung development, accompanied by a
deficiency in the production of surfactant. Surfactant is a substance that coats the alveoli
of the lungs in order to prevent their collapse (Picard et al., 2000). Furthermore, 65% of
infants born less than 1000g are affected by HMD/RDS, as compared to 10% to 20% of
premature infants that are born with this disorder.

One of the last organs to develop during fetal growth is the lungs. A lack of
adequate surfactant production from the immature lungs of infants with ELBW leads to
conditions such as RDS/HMD (Picard et al., 2000). RDS/HMD may, in turn, may lead to
bronchiopulmonary dysplasia (BPD; Picard et al., 2000), and other more long-term
conditions such as chronic lung disease (CLD; Watterberg et al., 1999) and asthma
of respiratory infections, bronchitis, and asthma in infancy decrease in later childhood. In
addition, no significant differences are observed in the prevalence of respiratory
infections and re-hospitalizations between children born with VLBW and controls by 8
years of age.

HMD/RDS in turn may lead to patent ductus arteriosus, extrapulmonary
extravasation of air, or BPD. The ductus arteriosus is a fetal blood vessel that joins the
aorta and the pulmonary artery, which generally closes in normal-term infants. This
closure is believed to be associated with a rise in oxygen saturation. With patent ductus
arteriosus, the ductus may remain open (patent) for several days or weeks and leads to
pulmonary edema (Picard et al., 2000). Extrapulmonary extravasation of air is the result
of the leakage of air from the lungs into other tissue. Specifically, it is associated with
pulmonary interstitial emphysema,
pneumomediastinum, and pneumothorax, which are the results of air in the pulmonary interstitial tissues, the anterior mediastinum, and the pleural cavity, respectively (Oh & Stern, 1987 cited in Picard et al., 2000).

Bronchiopulmonary dysplasia (BPD) is the most common of these three disorders and it is found most often in infants weighing less than 1000 g at birth. Furthermore, it is primarily observed in infants who require assisted ventilation. BPD may be accompanied by prolonged oxygen dependence and respiratory symptoms that persist for up to six months (Picard et al., 2000). The development of chronic lung disease resulting from adrenal insufficiency that frequently occurs in infants born with ELBW is also associated with BPD (Watterberg et al., 1999). BPD is thought to be due to a combination of alveolar damage from RDS/HMD, exposure to high oxygen concentrations from the respirator, the use of endotracheal intubation, and the prolonged duration of these treatments (Oh & Stern, 1987 cited in Picard et al., 2000).

In addition to respiratory type disorders, pre- or perinatal brain injury is also typically associated with LBW (Picard et al., 2000). There are three distinct pathologies that have been recognized in the brain of infants who are born preterm. The first is the previously discussed PVH/IVH, which occurs with or without posthemorrhagic hydrocephalus. The second is infarctive periventricular leukomalacia and the third is noninfarctive perinatal telencephalic leukoencephalopathy (Forfar et al., 1994). Each of these three pathologies is assumed to have different perinatal etiologies. Specifically, infarctive periventricular leukomalacia is likely due to ischemia and is best prevented by supporting myocardial function whereas noninfarctive perinatal telencephalic leukoencephalopathy has been linked to toxic and nutritional factors (Picard et al. 2000).
PVH/IVH can be defined as bleeding into the subependymal germinal matrix. The vulnerability of the germinal matrix to injury in infants with LBW plays a major role in the prevalence and pathogenesis of PVH/IVH. PVH/IVH occurs primarily in a premature infant who is born at less than 32 weeks gestation. There is also an increased risk for PVH/IVH in these infants when they have respiratory distress syndrome that is severe enough to require mechanical ventilation (intubation, respirator). In approximately 90% of PVH/IVH cases, the onset is within the first 72 hours of life.

PVH/IVH can range in severity from grade 1 to grade 4 with grade 1 being evidence of a hemorrhage in the germinal matrix with little to no intraventricular involvement and grade 4 being intracerebral involvement or other parenchymal lesions (Volpe, 1987 cited in Picard et al., 2000). PVH/IVH often leads to medical conditions that have found to be associated with LBW. Specifically, one of these associated conditions is hydrocephalus (Picard et al., 2000).

Subtle forms of injury, such as alterations of dendritic arborization and synaptogenesis, may be caused by one of the above-mentioned complications of PVH/IVH. These subtle forms of neuropathology may provide an explanation for some of the neurocognitive deficits that are found in children with ELBW (Picard et al., 2000).

Approximately 13% of preterm infants with PVH/IVH develop hydrocephalus (Dykes, Dunbar, Lazarra, & Ahmann, 1989), which leads to increased volumes of cerebral spinal fluid in the ventricles and compression of brain cells. Maximal effects of hydrocephalus are generally on the white matter and possible long-term consequences are cortical thinning, reduced brain mass, and cell necrosis of the gray matter (Fletcher et al., 1997).
The most common neurological abnormality found in children with LBW is cerebral palsy. Cerebral palsy is found in 10% to 20% of children born with ELBW and is associated with many neurosensory or neuromotor abnormalities that are found in these children (Hack et al., 2000; Picard et al., 2000). These impairments include abnormal posture and mobility, epilepsy, deafness, and visual problems (Picard et al., 2000).

In general, infants with VLBW who were the appropriate weight for gestational age appear to catch up to the normal population in height and weight some time between preschool and 8 years of age. In contrast, children with ELBW at 8 years of age are reported to be significantly lighter, shorter, and have a smaller mean head circumference as compared to normal controls (Saigal, 1995). It is important to note that medical conditions other than birth weight also affect cognitive and neurological development. Studies have found that the greatest contributions to gross motor and fine motor development, as measured by the Childhood Checklist (CC; Dean & Gray, 1985), are birth weight, viral infection, and tranquilizer use during pregnancy, child’s color at birth, and type of anesthesia used during delivery. Interestingly, speech development was also predicted by the same prenatal and perinatal factors, but to a lesser extent (Gaten, Arceneaux, Dean, & Anderson, 1994). For this reason, associated medical conditions should be taken into account when measuring the neuropsychological abilities of these children.

**Neuropsychological Sequelae**

The long-term outcome of infants with VLBW and ELBW in their school years is marked by increasing behavioural problems, problems in motor, visuomotor and perceptual skills, visual memory deficits, and language and reading difficulties, among
other problems (Levi-Shiff, Einat, Mogilner, Lerman, & Krikler, 1994; Spreen et al., 1995). Reports indicate that normal cognitive development is found in only 28% of surviving infants born at 24 weeks gestation (Martínez et al., 1998). Unfortunately, the prognosis tends to worsen in relation to increasingly lower birth weight (Levi-Shiff et al., 1994; Picard et al., 2000).

**Intelligence and Achievement Testing**

Picard et al. (2000) examined the relationship between increasingly lower birth weight and the levels of neuropsychological deficits found in children with LBW. They examined both an urban and suburban population of 6- to 7-year-old children who were born with LBW between 1983 and 1985. The neuropsychological battery included the Weschler Intelligence Scale for Children –Revised (WISC-R; Wechsler, 1974) and tests designed to measure language development, spatial skills, fine motor coordination, tactile perception, attention and memory. Regression analysis indicated a gradient relationship between birth weight and measure of neuropsychological functioning. Specifically, the lower the birth weight the poorer the child performed on tests of IQ and neuropsychological measures of language, visual-spatial, fine motor, tactile, and attention skills. This relationship was maintained when population site, maternal IQ, education, and race were controlled for and was repeated in a subset of children with Full Scale IQ (FSIQ) less than 80.

In comparison, Taylor et al. (1998) analyzed the prevalence neonatal risk and neuropsychological deficits in children with birth weights less than 1500 g who were tested between the ages of 5 and 9. Their results indicated that higher neonatal risk factor was the best predictor of lower IQ scores, verbal and perceptual motor abilities,
achievement test scores, adaptive behaviour scores, and higher parent ratings of overall behaviour problems. In contrast, lower birth weight was associated only with more deficits in math abilities, school performance, and higher parent ratings of overall behavioural problems. In addition, many studies report lower mean IQ and higher than normal incidence of academic difficulties at school in preterm infants (Saigal, 1995). As expected, a gradient of decreasing PIQ and VIQ has been observed with decreasing birth weight (Picard et al., 2000).

Rickards, Kelly, Doyle, and Callanan (2001) reported that adolescents with VLBW had mean scores in the low average range on all three (VIQ, PIQ, FSIQ) composite scores of the WISC-III, which was significantly lower than the performance of adolescents with NBW who scored in the average range on all three composite scores. Of the children with VLBW, 18% had FSIQ scores lower than 1 standard deviation below the mean. These results were consistent when adjustments for higher SES were made. Additionally, there was no significant difference in composite WISC-III scores among the adolescents with VLBW who had either necrotizing enterocolitis (NEC) or cerebroventricular hemorrhage (CVH). Interestingly, no significant difference was found between the adolescents of birth weight less than 1000 g and the adolescents of birth weight between 1000 and 1500 g (Rickards et al., 2001). When reviewing studies that examined test scores of children with ELBW exclusively, Saigal (1995) reported that two thirds of these infants had an IQ in the normal range at 8 years of age. However, the mean IQ score for these children was in the low average range. Further, 24% of the children with ELBW had IQ scores in the borderline range and 8% scored below 70.
Saigal, Hoult, Streiner, Stoskopf, and Rosenbaum, (2000) tested 12- and 16-year-old adolescents with ELBW on the Wide Range Achievement Test-Revised (WRAT-R) and five subtests of the Wechsler Intelligence Scale for Children-Revised (WISC-R). The subtests, Similarities, Mental Arithmetic, Vocabulary, Picture Arrangement, and Block to Design were used to measure a deviation quotient (DQ), which is highly correlated with full scale IQ (FSIQ). Results indicated that the mean DQ for all adolescents with ELBW was 13 points lower than for controls. Additionally, this group performed significantly poorer than controls on all three subtests of the WRAT-R, with mean standard scores in the range of 75 to 85. The adolescents in the smaller birth weight (less than 750 g) group showed significantly lower scores on both the Spelling and Arithmetic subtests of the WRAT-R as compared to adolescents with higher birth weights (750 g to 1000 g). These results were consistent when adolescents with neurosensory impairments and FSIQ scores of less than 85 were excluded from the analysis.

In order to compare possible gender differences in children with LBW and NBW, Johnson and Breslau (2000) tested both groups of children on the WISC-R and Woodcock-Johnson Psycho-Educational Battery- Revised. These results indicated that boys with LBW had a higher prevalence of both reading and math disabilities than did boys with NBW and that this difference was not significant when comparing girls with LBW and NBW.

In terms of cognitive development, Saigal (1995) reported that infants with ELBW that had shown sub-optimal performance on IQ tests at 2 years of age showed remarkable improvement when they reached 5 years of age. Saigal et al. (2000) also
tested children at 8 years old and then again in their teens (between 12 and 16) on the WRAT-R and five subtests of the WISC-R (DQ). Results indicated that for children with ELBW test scores in both Reading and Spelling improved over time but improvement in Spelling was minimal when compared to normal children. In Arithmetic, the standard scores of both groups of children decreased between the two time periods. In addition, performance in Arithmetic was lower for children with ELBW as compared to controls for both age groups.

**Biological and Psychosocial Risk Factors associated with Neuropsychological Sequelae**

Many of these neuropsychological results may be specifically related to other medical conditions and complications that surround the birth of a child with ELBW. For instance, HMD/RDS is mildly associated with hypoxia and it is well known that depriving the brain of oxygen for even a short period of time leads to necrosis of cells (Picard et al., 2000). Other medical problems such as IVH and cerebral palsy may be related to specific motor disabilities or visual acuity problems typically found in these children (Hack et al., 2000; Spreen et al., 1995). For this reason, it is important to note that several of the following studies have made great efforts to exclude children with many of these associated medical conditions in part of their analysis. This effort is made in an attempt to isolate the degree of deficits caused by LBW from the degree caused by neonatal complications and may eventually provide information to aid in the development of treatments. In some instances, the degree to which these conditions are closely related may lead to biases in the analysis of results.

Interestingly, Hack, Friedman, and Fanaroff (1996) found that despite increased availability of treatment and medical interventions for children with ELBW, the rates of
neonatal morbidity and neurodevelopmental outcomes at 20 months of age have not changed appreciably. Specifically, 20% of children in this population were found to have Bayley Mental Development Index (MDI; Bayley Scores of Infant Development, 1969/1994) scores in the range of subnormal cognitive functioning and 10% of these children were diagnosed with cerebral palsy.

In an attempt to assess the relative effects of both biological risk factors (i.e., birth weight and associated medical conditions) and psychosocial environmental factors, Levi-Shiff et al. (1994) compared adolescents with VLBW and NBW on IQ, visual-motor coordination, visual memory, reading comprehension, and hyperactive behaviour. Adolescents with VLBW demonstrated significantly lower IQ scores, poorer visual memory performance, and more hyperactive behaviour as compared to the NBW group. Further, the contribution of maternal attitudes and personal status, paternal environment, marital adjustment, and family climate to these variables was examined. Results indicated that psychosocial variables significantly predicted all outcome measures except visual memory.

More recent studies have revealed that medical complications mediated the relationship between birth status and Bayley MDI scores at 4 months and 13 months of age. However, no relationship was found between Bayley MDI scores and psychosocial factors at 4 and 13 months. In contrast, as compared to children at 4 and 13 months of age, no relationship was found between medical complications and Bayley MDI scores at 36 months. Instead, maternal distress rates and social support predicted Bayley MDI scores at this age. More specifically, children with LBW who were born to mothers reporting greater emotional distress exhibited more internalizing and externalizing
behaviour problems. In addition, children of mothers showing maternal social support exhibited fewer internalizing behaviour problems at 36 months (Miceli et al., 2000).

Other psychosocial factors that have been found to be correlated to cognitive development of infants with LBW, specifically, the child’s general level of intellectual functioning, are maternal IQ, marital status, income level, and home environment. The most important of these factors appears to be maternal IQ, which has been found to interact with the effects of other psychosocial variables measured (Bacharach & Baumeister, 1998).

Comorbidity

The majority of studies measuring IQ and achievement scores seem to reflect a high rate of learning disabilities (LD) in children with VLBW and ELBW. Even children with ELBW who have an IQ in the normal range show significantly poorer achievement scores than children with NBW. The majority of these significant differences appear to be in reading and math, and deficits appear to be more prevalent and perhaps more severe in boys than girls. Many researchers have analyzed whether or not these results indicate a higher prevalence of learning disabilities in children with ELBW (Johnson & Breslau, 2000; Saigal, 1995; Saigal et al., 2000). What is unclear is whether the LD in these children are predominantly verbal or nonverbal or whether both types occur.

A comparison of the prevalence of LD in children with ELBW and matched controls with NBW at the age of 8 years indicated that the prevalence of LD in children with ELBW, although slightly higher than that found in controls (26% compared to 19%, respectively), was not significantly different. However when compared to controls, significantly more children with ELBW were rated by their teachers as performing below
expected grade levels, and a higher proportion of these children had received special assistance in school (Saigal, Rosenbaum, Szatmari, & Campbell, 1991).

In contrast, when comparing children with ELBW and NBW between the ages of 12 to 16 years old, it was found that the children with ELBW had a significantly higher incidence of LD with a prevalence of 34% in the ELBW group as compared to 10% in the NBW group (Saigal, Stoskopf, Streiner, & Burrows, 2001). Additionally, children with ELBW were found to have a higher prevalence of visual problems (57% vs. 21%), seizures (7% vs. 1%), developmental delay (26% vs. 1%), and hyperactivity (9% vs. 2%) as compared to children with NBW.

Levi-Shiff et al. (1994) examined hyperactivity in both adolescents with VLBW and NBW, as assessed by teachers with the Conners Questionnaire (Conners, 1973). It was found that children with VLBW demonstrated significantly more hyperactivity behaviour as compared to controls. However, poorer maternal attitudes, more paternal involvement, and poor marital adjustment ratings also influenced increased hyperactivity behaviour.

In an examination of psychiatric sequelae in 6-year-old children who were born with LBW, Breslau et al. (1996a) found that the rate of ADHD was higher in children born with LBW as compared to children born with NBW. Furthermore, this association was stronger in children from urban as compared to suburban areas suggesting that SES may play an important role in the manifestation of ADHD symptoms in this population. Additionally, the authors found no significant association between LBW and the presence of anxiety disorder or oppositional defiant disorder (Breslau et al., 1996a).
It is important to note that parent and teacher ratings of children's behavioural problems may not be correlated (Kohen, Gunn, McCormick, & Graber, 1997). This may be a function of children exhibiting different behaviours while at school compared to at home, or could reflect some bias by either the parent or the teacher. Kohen et al. (1997) found that although mothers' reports of objective measures regarding their children were accurate, their assessments of behavioural problems and social competence often differed from those of teachers.

**Visual System and Visual Spatial Abilities**

The visual system is the last of the sensory systems to develop in the fetus (Picard et al., 2000). For this reason children born with ELBW are more likely to have underdeveloped visual systems at birth. In fact, children born with ELBW are 3.9 times more likely to be blind or have difficulty seeing as compared to children who were carried to term (Hack et al., 2000). Saigal (1995) reported that 24% of children with ELBW were wearing spectacles at 8 years of age as compared to 5% of matched controls.

Visual deficits are also associated with ELBW (Hack et al., 2000), and in general poor visual-spatial ability has been associated with low birth weight (Picard et al., 2000). Although visual-spatial ability is reported to be increasingly more severe with increasingly lower birth weight (Picard et al., 2000), the prevalence of blindness and severe visual problems caused by prematurity appear to be restricted to infants with ELBW (Saigal, 1995).

Waber and McCormick (1995) compared the complex visual skills of children with ELBW, VLBW, LBW, and NBW by measuring their performance on the Rey-
Osterrieth Complex Figure (ROCF; Lezak, 1983) test and the Beery-Buktenika Test of Visuomotor Integration (VMI; Beery, 1982). Results revealed significantly poorer performance in the children with ELBW as compared to the three other birthweight groups on the ROCF but no difference in their performance on the VMI. The poorer performance of the children with ELBW on the ROCF as compared to the VMI, and the types of errors made by this population on the ROCF may reflect deficits in visual perceptual processing skills in children with ELBW as opposed to deficits in visual attention (Waber & McCormick, 1995).

An additional analysis of neuropsychological abilities of 823 children with LBW and NBW who were evaluated at 6 years old, found that children born with LBW appear to have poorer visual-spatial skills as compared to NBW children. This result were found also when only children with a FSIQ IQ greater than 80 were included in the analysis (Breslau, Chilcoat, Del Dotto, Andreski, & Brown, 1996b).

In general, it appears that visual-spatial deficits are common in children with ELBW but it is important to remember that blindness and severe visual problems are also prevalent among these children (Hack et al., 2000). Therefore, although most studies make an attempt to test children with neuropsychological deficits, including visual disabilities, it is possible that a portion of the visual-spatial deficits found in ELBW children may be caused by a primary sensory impairment as opposed to a visual-spatial deficit.

**Attention and Memory**

As compared to children with NBW, children weighing less than 2500 g have been found to exhibit difficulty in focusing attention (Picard et al., 2000).
Neuropsychological assessment of children with ELBW revealed that scores of sustained attention are significantly lower for these children compared to children with VLBW and NBW (Taylor, Hack, Klein, & Schatschneider, 1995). Breslau et al. (1996b) found that at 6 years of age children with LBW performed significantly poorer on tests of focused attention as compared to children of the same age who were born with NBW. When children with an FSIQ of less than 80 were eliminated from the study, children with LBW continued to have significantly poorer performance than children with NBW on tests of focused attention. Consistent with other difficulties, this difficulty appears to be increasingly worse in children with increasingly lower birth weight (Picard et al., 2000).

Adolescents with VLBW have demonstrated significantly poorer visual memory performance as compared to NBW controls. The variability in the performance between the two groups could not be further accounted for by such psychosocial factors as maternal attitudes and personal status, paternal environment, marital adjustment, and family climate to these variables (Levi-Shiff et al., 1994). Rickards et al. (2001) also found poorer performance on tests of visual processing and visual memory in adolescents with VLBW. Specifically, this population received lower scores on both the Binet Bead Memory Test (Thorndike, Hagen, & Sattler, 1986) and the Organization Scale of the ROCF. However, adolescents with VLBW did not differ from adolescents with NBW in the accuracy of the copy portion of the ROCF when tested both directly and after a 3-minute delay.

More recent studies have found evidence of other possible memory deficits in children with LBW. The McCarthy Scales of Children’s Abilities (McCarthy, 1972) were used to compare the performance of 7-year-olds who were born between 24 and 28
weeks gestation with VLBW and children born full term with NBW. Results indicated that the children with VLBW who were born preterm were delayed with respect to perceptual performance, sequential memory, and motor performance (Nadeau, Boivin, Tessier, Lefebvre, & Robaey, 2001).

Verbal memory deficits in children with ELBW, VLBW, and NBW were compared using the California Verbal Learning Test-Children's Version (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994). Results indicated that children with ELBW performed more poorly in learning efficiency, free delayed recall, cued delayed recall, and inaccurate recall measures of the CVLT-C as compared to children with NBW. Performance of children with VLBW were also consistently poorer as compared to children with NBW but these scores were not significant (Taylor, Klein, Minich, & Hack, 2000).

In contrast, no significant differences were found in tests of vigilance and nonverbal memory in children with LBW as compared to controls at 6 years of age (Breslau et al., 1996b). Very few studies were found to measure different types of memory in children with ELBW. Further analysis is needed in order to determine possible weakness and/or strengths in the different types of memory for children in this population.

As shown, there is much evidence to suggest that children with LBW show both deficits in visual memory and verbal memory. However, there is a paucity of studies that compare different aspects of memory and the contribution of birth weight and biological risk factors to memory performance. Previous studies have also shown that children with LBW are likely to have a comorbid diagnosis of ADHD and/or LD.
Purpose and Hypotheses

The present study seeks to examine possible deficits in different aspects of memory functioning in children born with a birth weight less than 2500 g and to compare these deficits with children born with NBW who have been diagnosed with ADHD. In addition an examination of the contribution of IQ to these memory deficits will be performed. Children with ADHD have been chosen as the control group because they share many features with children born with LBW. Several hypotheses have been proposed for this analysis.

Hypothesis 1. It is expected that scaled scores on the Test of Memory and Learning (TOMAL; Reynolds & Bigler, 1997) will be positively correlated with birth weight, full-scale intelligence (FSIQ), a measure of receptive language skills (PPVT; Dunn & Dunn, 1981; Dunn & Dunn, 1997), a measure of visual motor integration (VMI), measures of visual and auditory attention (NEPSY; Korkman, Kemp, & Kirk, 2001), and measures of problem solving, set shifting, and set maintenance (WCST).

Hypothesis 2. It is expected that children with LBW will exhibit below average performance on the VMI as compared to norms and that scores in this domain will be significantly lower than that of children with NBW/ADHD.

Hypothesis 3. Children with LBW will exhibit below average performance on the PPVT in relation to norms and their scores in this domain will be poorer as compared to the performance of children in the NBW/ADHD groups.

Hypothesis 4. Due to previous evidence suggesting a high comorbidity of ADHD in children born with LBW (Breslau et al., 1996a), it is expected that no significant difference will be observed between the children in both the NBW/ADHD and the LBW group.
groups on measures of visual and auditory attention (NEPSY), problem solving, set shifting, and set maintenance abilities (WCST) as compared to children with LBW. Further, it is expected that both groups will exhibit below average performance in these domains in relation to norms.

Hypothesis 5. Children with LBW are also expected to perform more poorly on TOMAL measures as compared to both normative data and children with NBW/ADHD.

Hypothesis 6. Within the LBW and ADHD groups, scaled scores on the PPVT are expected to be better as compared to scaled scores on the VMI.

Hypothesis 7. It is expected that performance on the TOMAL across subjects will be significantly predicted by birth weight once variance predicted by IQ, and scaled scores on the PPVT, VMI, NEPSY visual and auditory attention subtests, and the WCST has been considered.
CHAPTER II

METHOD

Participants

Participants were collected through a retrospective chart review. All children had been referred to Henry Ford Health System in Detroit for neuropsychological testing between 1988 and 2001. The LBW group comprised was of 43 children between the ages of 5 and 13 who were born weighing less than 2500 g. All children in the low birth weight group had been given at least one comorbid diagnosis. Comorbid diagnoses included the following: ADHD (9 subjects), learning disability (LD-11 subjects), combined ADHD and LD (7 subjects), nonverbal learning disability (NLD-5 subjects), combined ADHD and NLD (7 subjects), mental retardation (MR-4 subjects), developmental delay (DD-2 subjects), speech/language delay (SLD-6 subjects), fetal alcohol syndrome (FAS-1 subject), and hydrocephalus (1 subject). The sum of comorbid diagnoses does not add up to 43, as some subjects had more than one comorbid diagnosis. Participants in the control group were children with birth weights of 2500 g or greater who had been diagnosed with ADHD based on neuropsychological test scores and criteria from the Diagnostic and Statistical Manual of Mental Disorders- 4th Edition, Text Revision (DSM-IV-TR; American Psychiatric Association, 2000). Control subjects were matched to subjects with LBW by age, gender, and parental education level as an indicator of SES (Durkin, Islam, Hasan, & Zaman, 1994).

Excluded from the analysis were subjects with severe neurological deficits, such as blindness and previous head injury for which their mental and/or motor disability was too severe to allow for full neuropsychological testing. Additionally, children with
comorbid psychiatric diagnoses or a history of substance or alcohol abuse were excluded from the analysis.

**Testing Procedures**

The children were assessed on a number of cognitive and neuropsychological variables in one-day sessions. Of the administered tests, those that were used in this analysis include the following: Wechsler Intelligence Scale for Children –3rd Edition (WISC-III; Wechsler, 1991), Stanford Binet Intelligence Test (Thorndike, Hagen, & Sattler, 1989), Beery Developmental Test of Visual Motor Integration (VMI; Beery, 1989), the Peabody Picture Vocabulary Test, revised (PPVT-R; Dunn & Dunn, 1981) or third edition (PPVT-III; Dunn & Dunn, 1997), Wisconsin Card Sorting Test (WCST; Heaton, 1981), auditory and visual attention subscales of the NEPSY (Korkman, Kemp, & Kirk, 2001), and the Test of Memory and Learning (TOMAL; Reynolds & Bigler, 1997). Additionally, parents or primary caregivers provided medical information for all children.

In order to assess visual-motor integration among the LBW and control groups, the VMI ($M = 100, SD = 15$) was administered to all children. Comparison of performance on this test with visual memory scores was used in order to examine the relationship between visual-motor integration ability and visual memory scores.

To assess receptive language ability between the LBW and control groups, the children were administered the PPVT ($M = 100, SD = 15$). Depending on the year of testing, the children were either administered the PPVT-R or the PPVT-III. Comparison of performance on this test with verbal memory scores was used to examine the relationship between receptive language ability and verbal memory scores.
In order to assess attention, problem solving, set shifting, and set maintenance abilities, children were administered both the visual and auditory attention subscales of the NEPSY \((M = 10, SD = 3)\) and the WCST \((M = 100, SD = 15)\). Comparison of these measures was conducted to assess features of ADHD in children born with LBW and to compare these with children with NBW who had been diagnosed with ADHD.

Children were administered either the WISC-III \((M = 100, SD = 15)\) or the Stanford Binet Intelligence \((M = 100, SD = 15)\) in order to assess general level of intellectual functioning. Full Scale IQ (FSIQ) scores have been used in order to examine the relationship between FSIQ and TOMAL scores.

Finally, children were administered both immediate and delayed recall tasks in four subscales of the TOMAL \((M = 10, SD = 3)\). As measures of verbal memory both the immediate and delayed portions of the TOMAL subscales, Memory for Stories and Word Selective Reminding were used. From these scores a verbal memory composite \((VM; M = 10, SD = 3)\) was established by taking the mean of the four subtests. As measures of visual or nonverbal memory both the immediate and delayed portion of the TOMAL subscales, Memory for Faces and Visual Selective Reminding scores were used. From these scores a nonverbal memory composite \((NM; M = 10, SD = 3)\) was established by taking the mean of the four subtests. In addition delayed memory index \((M = 100, SD = 3)\) scores were calculated for all children.

**Data Analysis**

Prior to formal testing of hypotheses the distributional properties of the birth weight groups were examined by generating frequency histograms, in order to measure possible deviations that may have a systematic effect on the neuropsychological variables
being examined. Skewed distribution of the birth weight groups may suggest a poor sampling of children with ELBW and VLBW, which would therefore result in poor statistical power in our ability to generalize results to children born with VLBW and ELBW.

To measure the degree to which TOMAL scores were related to IQ, birth weight, visual-motor integration, language, visual and auditory attention, and problem solving, set shifting, and set maintenance abilities a series of Pearson correlation analyses were performed. In addition, a correlation matrix was constructed in order to examine the relationships between possible predictor and criterion variables that will be used in the multiple regression analysis.

In order to compare mean differences in neuropsychological test scores between the two groups (NBW/ADHD, LBW) a series of independent sample t-tests were performed. The neuropsychological variables examined were visual-spatial integration (VMI), receptive language (PPVT), visual and auditory attention (NEPSY), memory scores (TOMAL), and problem solving (conceptual level responses), set shifting (perseverative errors), and set maintenance (failure to maintain set; WCST). The WCST scores examined were chosen as performance in these areas has been suggested to best represent the constructs under investigation in this study (Spreen & Strauss, 1998)

To examine relative performance on the PPVT versus the VMI within both the LBW and NBW/ADHD groups a paired sample t-test was performed. Finally, simple and multiple regression analyses were performed in order to assess the relationship between the predictor variables of birth weight, IQ, VMI scores, PPVT scores, NEPSY scores, WCST scores, and TOMAL scores.
CHAPTER III

RESULTS

Preliminary analysis of the distributional properties of the birth weight sample revealed that the frequency of birth weights of all subjects (Figure 1) is slightly negatively skewed (i.e., -.209). This suggests that there is a smaller distribution of birth weight in the NBW group as compared to the LBW group. Further analysis of the distributional properties of the birth weight categories (NBW, LBW, VLBW, ELBW) as outlined by the World Health Organization (1963) revealed a highly positively skewed (i.e., 1.126) distribution of subjects in each birth weight category (Figure 2). This result is due to the fact that few subjects in the LBW group fall into the VLBW or ELBW categories. This suggests that there is poor statistical power when trying to generalize results to children who were born with VLBW or ELBW.

Hypothesis 1

A series of Pearson-product correlations were conducted to measure the relationship between possible predictor variables and TOMAL scores (Table 1). The potential predictor variables analyzed were birth weight, full-scale intelligence (FSIQ), receptive language (PPVT), visual-motor integration (VMI), auditory and visual attention, problem solving, set shifting, and set maintenance (WCST). Results of correlations between birth weight and TOMAL scores revealed a significant relationship between birth weight and the nonverbal memory composite (NM) $r = .309, p = .016$. When relationships between birth weight and the four nonverbal subtests were examined only a significant correlation with the delayed portion of the visual selective reminding (VSR) subtest was found, $r = .328, p = .010$. This suggests that the majority of the
Table 1.

Mean and standard deviation scores on for NBW/ADHD and LBW groups on all measures.

<table>
<thead>
<tr>
<th></th>
<th>NBW/ADHD</th>
<th></th>
<th>LBW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Age</td>
<td>8.51</td>
<td>2.31</td>
<td>8.51</td>
<td>2.31</td>
</tr>
<tr>
<td>IQ</td>
<td>92.55</td>
<td>17.26</td>
<td>85.07</td>
<td>18.55</td>
</tr>
<tr>
<td>VMI</td>
<td>89.03</td>
<td>12.42</td>
<td>84.41</td>
<td>15.57</td>
</tr>
<tr>
<td>PPVT</td>
<td>97.20</td>
<td>22.65</td>
<td>88.55</td>
<td>15.86</td>
</tr>
<tr>
<td>NEPSY visual attention</td>
<td>9.52</td>
<td>3.96</td>
<td>7.73</td>
<td>2.78</td>
</tr>
<tr>
<td>NEPSY auditory attention</td>
<td>9.05</td>
<td>1.94</td>
<td>8.70</td>
<td>2.97</td>
</tr>
<tr>
<td>WCST perseverative errors</td>
<td>95.24</td>
<td>19.15</td>
<td>93.45</td>
<td>18.43</td>
</tr>
<tr>
<td>WCST conceptual level responses</td>
<td>95.93</td>
<td>16.49</td>
<td>92.81</td>
<td>18.65</td>
</tr>
<tr>
<td>WCST failure to maintain set</td>
<td>1.23</td>
<td>1.17</td>
<td>1.13</td>
<td>1.26</td>
</tr>
<tr>
<td>TOMAL DRI</td>
<td>97.62</td>
<td>9.50</td>
<td>90.85</td>
<td>7.86</td>
</tr>
<tr>
<td>TOMAL VM composite</td>
<td>9.87</td>
<td>2.18</td>
<td>9.01</td>
<td>2.11</td>
</tr>
<tr>
<td>TOMAL NM composite</td>
<td>8.75</td>
<td>1.42</td>
<td>7.76</td>
<td>1.27</td>
</tr>
</tbody>
</table>
Figure 1. Histogram of the distribution of the birth weights of all subjects
Figure 2. Histogram of the distribution of subjects in each birth weight category with 1.0 representing NBW, 2.0 representing LBW, 3.0 representing VLBW, and 4.0 representing ELBW.
relationship between nonverbal memory (NM) and birth weight is associated with performance on the delayed portion of the VSR subtest.

Analysis of the relationship between FSIQ and memory scores revealed a significant positive correlation between memory scores, except both the immediate and delayed portions of the facial memory (FM) subtests (Table 1).

In comparing the relationship between verbal memory subtests of the TOMAL and performance on the PPVT a significant correlation was found between the PPVT and both the VM and NM composite scores, $r = .442, p = .013$ and $r = .363, p = .048$, respectively. Of the verbal memory subtests, significant positive correlations were found for both the Memory for Stories, immediate memory subtest (MS) $r = .584, p = .001$ and the MS, delayed recall subtest $r = .498, p = .004$. This suggests that the majority of the relationship between VM and performance on the PPVT is related to performance on the MS subtests.

Examination of the relationship between visual memory subtests of the TOMAL and performance on the VMI revealed no significant relationships between these tests scores (Table 1). This suggests that performance on the VMI does not account for a significant portion of the variance in visual memory scores.

In comparing the relationship between scores on the WSCT and NEPSY attention subtests and TOMAL performance several significant correlations were found (Table 1). The VM composite was significantly correlated with performance on the NEPSY attention/executive domain, $r = .452, p = .035$, and NEPSY auditory attention, $r = .398, p = .036$. The NM composite was significantly correlated with performance on the NEPSY visual attention task, $r = .398, p = .463$. Further, the delayed recall index (DRI) of the
Table 2
Pearson Correlation values for relationship between TOMAL scores and FSIQ, PPVT, VMI, WCST, and NEPSY scores for all subjects

|                      | BRD | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL | TOMAL |
|----------------------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| FSIQ                 | .545* | .494* | .444* | .552* | .499* | .244* | .280* | .159  | .118  | .423* | .399* |
| Sig.                 | .000 | .000  | .000  | .000  | .000  | .027  | .011  | .220  | .370  | .001  | .002  |
| PPVT                 |     |       | .442* | .363* | .584* | .498* | .103  | .245  |       |       |       |       |       |       |
| Sig.                 |     | .013  | .048  | .001  | .004  | .580  | .183  |       |       |       |       |       |       |       |
| VMI                  |     | .209  | .252  | .208  | .155  | .656  | .906  | .046  | .076  | .124  | .308  |       |       |       |
| Sig.                 | .119 | .069  | .069  | .069  | .069  | .069  | .069  | .069  | .069  | .069  | .069  |       |       |       |
| WCST                 | .132 | .099  | .173  | .196  | .220  | .059  | .016  | .046  | .076  | .124  | .308  |       |       |       |
| Perseverative Sig. Responses | .417 | .526  | .287  | .208  | .155  | .656  | .906  | .778  | .640  | .444  | .053  |       |       |       |
| WCST                 | .136 | .099  | .159  | .194  | .223  | .073  | .006  | .036  | .079  | .102  | .315* |       |       |       |
| Perseverative Sig. errors | .401 | .529  | .327  | .212  | .150  | .583  | .963  | .825  | .640  | .532  | .025  |       |       |       |
| WCST                 | .203 | .169  | .155  | .235  | .244  | .042  | .070  | .158  | .125  | .240  | .400* | .011  |       |       |
| conceptual Sig. level responses | .208 | .279  | .340  | .129  | .115  | .750  | .597  | .330  | .444  | .135  | .011  |       |       |       |
| WCST                 | -.164 | -.011 | -.221 | -.021 | -.091 | .032  | .030  | -.192 | -.245 | -.049 | .085  | .593  |       |       |
| failure to Sig. maintain set | .300 | .944  | .160  | .893  | .551  | .806  | .821  | -.222 | .118  | .760  | .289  |       |       |       |
| NEPSY                | .484* | .452* | .243  | .539* | .521* | .316  | .406* | -.030 | .049  | .238  | .313  | .216  |       |       |
| attention/executive domain | .030 | .035  | .303  | .010  | .016  | .050  | .010  | .898  | .837  | .313  | .289  |       |       |       |
| NEPSY                | .199 | .219  | .161  | .232  | .110  | .277  | .274  | -.031 | .013  | .133  | .163  |       |       |       |
| auditory response set | .341 | .273  | .442  | .235  | .386  | .076  | .079  | .879  | .952  | .517  | .427  |       |       |       |
| NEPSY                | .391* | .398* | .199  | .457* | .345  | .342* | .388* | .045  | .090  | .141  | .175  | .382  |       |       |
| auditory attention | .048 | .036  | .329  | .013  | .072  | .022  | .009  | .823  | .664  | .482  | .382  |       |       |       |
| NEPSY                | .479* | .355  | .427* | .174  | .162  | .301* | .260  | .083  | .369  | .213  | .259  |       |       |       |
| visual attention | .013 | .664  | .030  | .368  | .409  | .047  | .088  | .682  | .064  | .285  | .192  |       |       |       |
| NEPSY                | .457* | .463* | .083  | .485* | .408* | .397* | .476* | -.027 | .164  | .019  | .089  |       |       |       |
| auditory attention task | .013 | .015  | .693  | .009  | .035  | .009  | .001  | .897  | .435  | .926  | .667  |       |       |       |
| Birth Weight         | .253 | .098  | .309* | .063  | .126  | -.004 | .015  | .189  | .109  | .137  | .328* | .010  |       |       |

Note. * indicates significance, p < .05
TOMAL was significantly correlated with performance on the NEPSY attention/executive domain, \( r = .484, p = .030 \), NEPSY auditory attention composite, \( r = .391, p = .048 \), and the NEPSY visual attention task, \( r = .479, p = .013 \).

Analysis of the relationship between NEPSY and WCST scores and individual TOMAL subtest scores revealed significant correlations with memory for stories (MS) immediate and delayed subtests, word selective reminding (WSR) immediate and delayed subtests, and visual selective reminding (VSR) delayed subtest (Table 1).

The immediate portion of the TOMAL MS subtest was found to be significantly correlated with the NEPSY attention/executive domain, \( r = .484, p = .030 \), and the NEPSY auditory attention composite score, \( r = .457, p = .013 \). The delayed portion of the TOMAL MS subtest was significantly correlated with both the NEPSY attention/executive domain score, \( r = .539, p = .010 \) and the NEPSY simple auditory attention subtest, \( r = .457, p = .013 \).

The immediate portion of the TOMAL WSR subtest was found to be significantly correlated with the NEPSY visual attention subtest, \( r = .301, p = .047 \), and the NEPSY auditory attention composite, \( r = .342, p = .022 \). The delayed portion of the TOMAL WSR subtest was found to be significantly correlated with the NEPSY attention/executive domain, \( r = .406, p = .010 \), and the NEPSY auditory attention composite, \( r = .388, p = .009 \).

Finally, the delayed portion of the TOMAL VSR subtest was significantly correlated with WSCT perseverative errors, \( r = .315, p = .048 \), and WSCT conceptual level responses, \( r = .400, p = .011 \).
The only TOMAL subtests that were not significantly correlated with any of the suggested predictors were both the immediate and delayed FM subtests. This suggests that no significant predictors of performance on these subtests were revealed in this analysis.

**Hypothesis 2**

Standard scores on a test of visual-motor integration between the two groups (LBW, NBW/ADHD) were compared in order to examine the possible relationship between variance in visual memory scores and performance on a measure of visual-motor integration. It was hypothesized that children in the LBW group would exhibit below average performance on the VMI as compared to norms and that their scores would be significantly lower than that of children in the NBW/ADHD group.

Comparison of the standard scores between the two groups on the Beery Developmental Test of Visual Motor Integration (VMI) was accomplished by conducting an independent samples t-test. The mean standard scores for the NBW/ADHD group ($M = 89.03, SD = 12.42$) and the LBW group ($M = 84.41, SD = 15.57$) were both in the low average range as compared to norms. The distribution of standard scores on the VMI for both the NBW/ADHD and LBW groups is displayed in Figure 3. Although the mean for the NBW/ADHD group was slightly higher than that of the LBW group, no significant difference was found $t (59) = 1.286, p = .203$. 
Figure 3. Distribution of VMI standard scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.
Hypothesis 3

Similarly, standard scores on a test of receptive language ability between the two groups (LBW, NBW/ADHD) were compared in order to examine the possible relationship between variance in verbal memory scores and receptive language abilities. It was hypothesized that children in the LBW group would exhibit below average performance on the PPVT as compared to norms and that their performance would be significantly lower than that of children in the NBW/ADHD group.

A comparison of scores between the two groups on the Peabody Picture Vocabulary Test (PPVT) was conducted with an independent samples t-test. Results of the analysis revealed that mean standard scores for the NBW/ADHD group ($M = 97.20, SD = 22.65$) and the LBW group ($M = 88.55, SD = 15.86$) were in the average range for the NBW/ADHD group and the low average range for the LBW group. The distribution of standard scores on the PPVT for both the NBW/ADHD and LBW groups is displayed in Figure 4. Although the mean for the NBW/ADHD groups was slightly higher than that of the LBW group, no significant difference was found $t(29) = 1.121, p = .271$.

Hypothesis 4

A comparison of scores on measures of auditory and visual attention, problem solving, set shifting, and set maintenance were conducted in order to examine the possible relationship between variance in memory scores and performance in these domains. It was hypothesized that children in both the LBW and NBW/ADHD groups would exhibit below average performance on measures of attention, problem solving, set shifting, and set maintenance as compared to norms. However, it was predicted that there would be no significant difference between the two groups on these measures as a high
Figure 4. Distribution of PPVT standard scores both all subjects in the NBW/ADHD (above) and LBW (below) groups.
comorbidity of ADHD in the LBW group was expected. Frequency analysis of comorbid diagnoses in the LBW group revealed that the comorbidity of ADHD in the LBW group was 50%.

A series of independent sample t-tests were performed in order to compare scores between the two groups on the WCST and NEPSY subtests. With the exception of the NEPSY auditory response set and visual attention subtests, all other WSCT and NEPSY mean scores were in the average range. The mean NEPSY auditory response set scaled scores were in the low average range for both the ADHD/NBW and LBW groups (Table 2). For the NEPSY visual attention subtest the mean scaled score for the ADHD/NBW group was in the average range \( (M = 9.52, SD = 3.96) \), whereas the scaled score for the LBW group was in the low average range \( (M = 7.73, SD = 2.78) \). The distribution of NEPSY auditory attention, NEPSY visual attention scaled scores, and WCST perseverative errors and conceptual level response standard scores for both groups are displayed in Figures 5 through 8 respectively. For all WSCT and NEPSY measures, mean scores were consistently poorer for the LBW group as compared to the ADHD/NBW group with the exception of the NEPSY auditory attention task \( (M = 10.04, SD = 2.96; M = 9.90, SD = 1.92, \text{ respectively}) \). However, there was no significant difference between the groups on any of the WSCT and NEPSY measures (Table 3). Only the difference between scaled scores on the NEPSY visual attention task between the two groups approached significance \( t(45) = 1.822, p = .075 \).
Figure 5. Distribution of NEPSY auditory attention scaled scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.
Figure 6. Distribution of NEPSY visual attention scaled scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.
Figure 7. Distribution of WCST perseverative errors standard scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.
Figure 8. Distribution of WCST conceptual level response standard scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.
## Table 3
Mean NEPSY and WCST standard scores for NBW/ADHD and LBW groups

<table>
<thead>
<tr>
<th>Group Statistics</th>
<th>Birth weight group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEPSY auditory attention</td>
<td>NBW/ADHD</td>
<td>21</td>
<td>9.05</td>
<td>1.94</td>
<td>.42</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>27</td>
<td>8.70</td>
<td>2.97</td>
<td>.57</td>
</tr>
<tr>
<td>NEPSY visual attention</td>
<td>NBW/ADHD</td>
<td>21</td>
<td>9.52</td>
<td>3.96</td>
<td>.86</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>26</td>
<td>7.73</td>
<td>2.78</td>
<td>.55</td>
</tr>
<tr>
<td>NEPSY attention task</td>
<td>NBW/ADHD</td>
<td>20</td>
<td>9.90</td>
<td>1.92</td>
<td>.43</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>24</td>
<td>10.04</td>
<td>2.96</td>
<td>.60</td>
</tr>
<tr>
<td>NEPSY attention/executive domain</td>
<td>NBW/ADHD</td>
<td>16</td>
<td>93.06</td>
<td>12.47</td>
<td>3.12</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>24</td>
<td>89.83</td>
<td>18.48</td>
<td>3.77</td>
</tr>
<tr>
<td>WCST perseverative errors</td>
<td>NBW/ADHD</td>
<td>29</td>
<td>95.24</td>
<td>19.15</td>
<td>3.56</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>31</td>
<td>93.45</td>
<td>18.43</td>
<td>3.31</td>
</tr>
<tr>
<td>WCST conceptual level responses</td>
<td>NBW/ADHD</td>
<td>29</td>
<td>95.93</td>
<td>16.49</td>
<td>3.06</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>31</td>
<td>92.81</td>
<td>18.65</td>
<td>3.35</td>
</tr>
<tr>
<td>WCST failure to maintain set</td>
<td>NBW/ADHD</td>
<td>30</td>
<td>1.23</td>
<td>1.17</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>32</td>
<td>1.13</td>
<td>1.26</td>
<td>.22</td>
</tr>
<tr>
<td>NEPSY auditory response set</td>
<td>NBW/ADHD</td>
<td>20</td>
<td>8.05</td>
<td>2.19</td>
<td>.49</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>24</td>
<td>7.92</td>
<td>2.99</td>
<td>.61</td>
</tr>
</tbody>
</table>
Table 4
Independent sample t-test scores for comparison of mean standard NEPSY and WSCT scores between LBW and NBW/ADHD groups

<table>
<thead>
<tr>
<th></th>
<th>t-test for Equality of Means</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>df</td>
<td>Sig. (2-tailed)</td>
<td>Mean Difference</td>
<td>Std. Error Difference</td>
<td>95% Confidence Interval of the Difference</td>
<td></td>
</tr>
<tr>
<td>NEPSY auditory attention</td>
<td>.459</td>
<td>46</td>
<td>.648</td>
<td>.34</td>
<td>.75</td>
<td>-1.16</td>
<td>1.85</td>
</tr>
<tr>
<td>NEPSY visual attention</td>
<td>1.822</td>
<td>45</td>
<td>.075</td>
<td>1.79</td>
<td>.98</td>
<td>-.19</td>
<td>3.78</td>
</tr>
<tr>
<td>Attention task</td>
<td>-.184</td>
<td>42</td>
<td>.855</td>
<td>-.14</td>
<td>.77</td>
<td>-1.69</td>
<td>1.41</td>
</tr>
<tr>
<td>NEPSY attention/executive domain</td>
<td>.611</td>
<td>38</td>
<td>.545</td>
<td>3.23</td>
<td>5.29</td>
<td>-7.47</td>
<td>13.93</td>
</tr>
<tr>
<td>WCST perseverative errors</td>
<td>.369</td>
<td>58</td>
<td>.714</td>
<td>1.79</td>
<td>4.85</td>
<td>-7.92</td>
<td>11.50</td>
</tr>
<tr>
<td>WCST conceptual level responses</td>
<td>.686</td>
<td>58</td>
<td>.496</td>
<td>3.12</td>
<td>4.56</td>
<td>-6.00</td>
<td>12.25</td>
</tr>
<tr>
<td>WCST failure to maintain set</td>
<td>.350</td>
<td>60</td>
<td>.727</td>
<td>.11</td>
<td>.31</td>
<td>-.51</td>
<td>.73</td>
</tr>
<tr>
<td>Response set</td>
<td>.166</td>
<td>42</td>
<td>.869</td>
<td>.13</td>
<td>.80</td>
<td>-1.49</td>
<td>1.76</td>
</tr>
</tbody>
</table>
Hypothesis 5

In order to compare standard scores on the Test of Memory and Learning (TOMAL) between the groups, a series of independent samples t-tests were used. It was hypothesized that children in the LBW group would demonstrate significantly poorer performance on memory subtests as compared to children in the NBW/ADHD group.

The mean TOMAL scores for both groups were in the average range with the exception of the visual or nonverbal memory (NM) composite scores and the immediate recall scores on the Visual Selective Reminding subtest (VSR) which were all in the low average range for both groups (Table 4). The distribution of TOMAL NM, verbal memory (VM), and delayed recall index (DRI) scores for both groups are displayed in Figure 9, Figure 10, and Figure 11 respectively. For all TOMAL measures, mean scores were consistently poorer for the LBW group as compared to the ADHD/NBW group (Table 5), however significant differences between the two groups were with the DRI $t(58) = 2.944, p = .005$, the NM composite scores $t(58) = 2.806, p = .007$, and the VSR delayed recall scores $t(58) = 2.716, p = .009$.

Hypothesis 6

In order to determine whether children within the LBW and NBW/ADHD groups demonstrate poorer performance on a test of visual-motor integration (VMI) as compared to a test of receptive language ability (PPVT), a paired sample t-test was performed. For the NBW/ADHD group a significant correlation between the two tests was found, $r = .567, p = .018$. However, this trend was not found in the LBW group. For both groups,
Figure 9. Distribution of TOMAL VM composite scores for all subjects in the NBW/ADHD (above) and the LBW (below) groups.
Figure 10. Distribution of TOMAL NM composite scores for all subjects in the NBW/ADHD (above) and LBW (below) groups.
Figure 11. Distribution of TOMAL DRI scores for all subjects in NBW/ADHD (above) and LBW (below) groups.
Table 5  
Mean scores for NBW/ADHD and LBW groups on TOMAL subtests

<table>
<thead>
<tr>
<th>Group Statistics</th>
<th>Birth weight group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMAL delayed recall index</td>
<td>NBW/ADHD</td>
<td>34</td>
<td>97.62</td>
<td>9.50</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>26</td>
<td>90.85</td>
<td>7.86</td>
<td>1.54</td>
</tr>
<tr>
<td>TOMAL memory for stories immediate</td>
<td>NBW/ADHD</td>
<td>35</td>
<td>10.40</td>
<td>2.72</td>
<td>.46</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>32</td>
<td>9.69</td>
<td>2.87</td>
<td>.51</td>
</tr>
<tr>
<td>TOMAL memory for stories delay</td>
<td>NBW/ADHD</td>
<td>34</td>
<td>10.00</td>
<td>2.83</td>
<td>.49</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>31</td>
<td>9.00</td>
<td>2.65</td>
<td>.48</td>
</tr>
<tr>
<td>TOMAL wd selective reminding immediate</td>
<td>NBW/ADHD</td>
<td>41</td>
<td>9.07</td>
<td>3.07</td>
<td>.48</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>41</td>
<td>8.90</td>
<td>3.47</td>
<td>.54</td>
</tr>
<tr>
<td>TOMAL wd selection remind delay</td>
<td>NBW/ADHD</td>
<td>41</td>
<td>10.02</td>
<td>1.98</td>
<td>.31</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>41</td>
<td>9.76</td>
<td>1.92</td>
<td>.30</td>
</tr>
<tr>
<td>TOMAL Facial memory immediate</td>
<td>NBW/ADHD</td>
<td>34</td>
<td>8.68</td>
<td>2.53</td>
<td>.43</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>27</td>
<td>7.81</td>
<td>2.11</td>
<td>.41</td>
</tr>
<tr>
<td>TOMAL Facial memory delay</td>
<td>NBW/ADHD</td>
<td>34</td>
<td>9.21</td>
<td>2.20</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>26</td>
<td>8.69</td>
<td>1.23</td>
<td>.24</td>
</tr>
<tr>
<td>TOMAL Visual selective Reminding immediate</td>
<td>NBW/ADHD</td>
<td>33</td>
<td>7.82</td>
<td>3.00</td>
<td>.52</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>27</td>
<td>6.59</td>
<td>2.48</td>
<td>.48</td>
</tr>
<tr>
<td>TOMAL Visual Selective remining delay</td>
<td>NBW/ADHD</td>
<td>33</td>
<td>9.33</td>
<td>1.76</td>
<td>.31</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>27</td>
<td>8.07</td>
<td>1.82</td>
<td>.35</td>
</tr>
<tr>
<td>Average of 4 verbal memory subtests</td>
<td>NBW/ADHD</td>
<td>35</td>
<td>9.871</td>
<td>2.184</td>
<td>.369</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>30</td>
<td>9.008</td>
<td>2.110</td>
<td>.385</td>
</tr>
<tr>
<td>Average of 4 visual memory subtests</td>
<td>NBW/ADHD</td>
<td>34</td>
<td>8.750</td>
<td>1.417</td>
<td>.243</td>
</tr>
<tr>
<td></td>
<td>LBW</td>
<td>26</td>
<td>7.760</td>
<td>1.268</td>
<td>.249</td>
</tr>
</tbody>
</table>
Table 6
Independent sample t-test scores for comparison of mean standard TOMAL scores between LBW and NRW/DW.

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Samples Test</td>
<td>2.944</td>
<td>58</td>
<td>.005</td>
<td>6.77</td>
<td>2.30</td>
<td>Lower: 2.17, Upper: 11.37</td>
</tr>
<tr>
<td>TOMAL memory for stories immediate</td>
<td>1.043</td>
<td>65</td>
<td>.301</td>
<td>.71</td>
<td>.68</td>
<td>Lower: -.65, Upper: 2.08</td>
</tr>
<tr>
<td>TOMAL memory for stories delay</td>
<td>1.468</td>
<td>63</td>
<td>.147</td>
<td>1.00</td>
<td>.68</td>
<td>Lower: -.36, Upper: 2.36</td>
</tr>
<tr>
<td>TOMAL wd selective reminding immediate</td>
<td>.236</td>
<td>80</td>
<td>.814</td>
<td>.17</td>
<td>.72</td>
<td>Lower: -1.27, Upper: 1.61</td>
</tr>
<tr>
<td>TOMAL wd selection remind delay</td>
<td>.623</td>
<td>80</td>
<td>.535</td>
<td>.27</td>
<td>.43</td>
<td>Lower: -.59, Upper: 1.13</td>
</tr>
<tr>
<td>TOMAL Facial memory immediate</td>
<td>1.419</td>
<td>59</td>
<td>.161</td>
<td>.86</td>
<td>.61</td>
<td>Lower: -.35, Upper: 2.08</td>
</tr>
<tr>
<td>TOMAL Facial memory delay</td>
<td>1.069</td>
<td>58</td>
<td>.289</td>
<td>.51</td>
<td>.48</td>
<td>Lower: -.45, Upper: 1.47</td>
</tr>
<tr>
<td>TOMAL Visual selective Reminding immediate</td>
<td>1.697</td>
<td>58</td>
<td>.095</td>
<td>1.23</td>
<td>.72</td>
<td>Lower: -.22, Upper: 2.67</td>
</tr>
<tr>
<td>TOMAL visual selective reminding delay</td>
<td>2.716</td>
<td>58</td>
<td>.009</td>
<td>1.26</td>
<td>.46</td>
<td>Lower: -.33, Upper: 2.19</td>
</tr>
<tr>
<td>Average of 4 verbal memory subtests</td>
<td>1.613</td>
<td>63</td>
<td>.112</td>
<td>.863</td>
<td>2.944</td>
<td>Lower: 3, Upper: 2.944</td>
</tr>
<tr>
<td>Average of 4 visual memory subtests</td>
<td>2.806</td>
<td>58</td>
<td>.007</td>
<td>.990</td>
<td>1.468</td>
<td>Lower: .63, Upper: .147</td>
</tr>
</tbody>
</table>
mean performance on the VMI was lower than mean performance on the PPVT, however this difference was not significant for either the NBW/ADHD group \( t (16) = -1.466, p = .162 \) or the LBW group \( t (9) = -.701, p = .501 \).

**Hypothesis 7**

Further analyses of the relationships between predictor variables (Birth weight, FSIQ, PPVT, VMI, NEPSY, and WCST) and TOMAL scores were conducted in order to determine the degree to which variance in TOMAL scores may be related to variance in predictor variables, especially birth weight. As revealed by the analysis of Hypothesis 1, birth weight was found to be significantly correlated with only the TOMAL NM composite \( (r = .309, p = .016) \). It is suggested that the majority of this relationship is due to positive correlations between the delayed portions of the TOMAL VSR subtest \( (r = .328, p = .010) \). As such, it is suggested that only variance in the TOMAL NM composite score can be predicted by birth weight. Further, the only significant predictors of performance on the TOMAL NM composite score were found to be FSIQ \( (r = .444, p = .000) \), performance on the PPVT \( (r = .363, p = .048) \), and performance on the NEPSY visual attention subtest \( (r = .427, p = .000) \).

In order to determine whether birth weight significantly predicts variance in TOMAL NM composite scores after variance predicted by IQ, PPVT scores, and NEPSY visual attention scores has been accounted for, a stepwise multiple regression analysis was performed. As IQ and performance on the PPVT were found to be highly correlated \( (r = .763, p = .000) \), multiple regression analyses with PPVT scores and birth weight as predictors were run separately.
The first stepwise regression analysis was conducted by entering IQ and NEPSY visual attention scores as a block of covariates and then adding birth weight in the next step to determine if birth weight significantly predicts variance in TOMAL NM scores after accounting for the variance predicted by IQ and visual attention scores. Results indicated that visual attention and IQ significantly predicted variance in NM scores. \( F(2, 23) = 3.309, p = .055 \) and that together IQ and visual attention accounted for 22.3 \% \( (R^2 = .223) \) of the variance in NM scores. When birth weight was added to the model 29.2 \% \( (R^2 = .292) \) of the variance in NM scores was accounted for and all three predictor variables contributed to a significant amount of the variance in NM scores. \( F(3, 22) = 3.020, p = .051 \). However, \( \Delta R^2 = .068 \) was not significant after adding birth weight to the model, \( F(1, 22) = .119, p = .160 \). This suggests that birth weight does not significantly predict variance in TOMAL NM scores, after accounting for the variance predicted by IQ and visual attention.

The second stepwise regression analysis was conducted by first entering PPVT scores into the model as a covariate and then adding birth weight in the next step in order to determine if birth weight significantly predicts variance in TOMAL NM scores after accounting for variance predicted by PPVT scores. Results indicated that PPVT scores predicted a significant amount of variance in NM scores. \( F(1, 28) = 4.258, p = .048 \) and that PPVT scores alone accounted for 13.2 \% \( (R^2 = .132) \) of the variance in NM scores. When birth weight was added to the model 17.4\% \( (R^2 = .174) \) of the variance in NM scores was accounted for however a significant amount of variance in NM scores was not accounted for by this model, \( F(2, 27) = 2.837, p = .076 \). As with the previous model \( \Delta R^2 = .042 \) was not significant after adding birth weight to the model. \( F(1, 27) = 1.361, p = \)
Results of the regression analyses suggest that increases in NM scores are significantly predicted by increases in IQ, PPVT scores and NEPSY visual attention scores. Furthermore, once variance in these test scores had been accounted for birth weight did not predict a significant amount of variance in TOMAL NM scores.
CHAPTER IV

DISCUSSION

The purpose of this study was to examine possible deficits in different aspects of memory, (visual, verbal, and delayed recall) in children born with low birth weight and to compare these deficits with children born with NBW who have been diagnosed with ADHD. Children with ADHD were used as a control group in order to control for the fact that these children share many features with children born with LBW. Furthermore, an attempt was made to examine (1) whether variance in memory scores could be accounted for by primary deficits in either visual motor integration or language abilities and (2) the ability of birth weight to predict variance in memory scores after accounting for variance predicted by IQ, visual-motor integration, receptive language ability, attention, planning and set shifting abilities. Seven hypotheses were proposed.

First correlations between memory scores and all possible predictors were conducted in order to determine which of these predictors had a significant relationship with TOMAL memory scores. Hypothesis 1 stated that there would be a positive linear relationship between scaled scores on the TOMAL and birth weight. IQ, language abilities, visual-motor integration abilities, scores in visual and auditory attention, and scores on a measures of problem solving, set shifting, and set maintenance abilities. Results of this analysis revealed several significant correlations (Table 1), however only TOMAL NM composite scores and scores on the VSR task were found to have a significant positive relationship with birth weight. Results of this analysis are inconsistent with findings of Levi-Shiff et al. (1994) and Picard et al. (2000), which suggest that performance on tests of IQ, language, fine motor, visual-spatial tactile, and
attention skills tends to decrease with decreasing birth weight. Inconsistencies in these results, with respect to previous findings are likely related to the fact that the majority of LBW subjects in our analysis weighed between 2500 g and 1500 g. It is likely that if the range of birth weight were more evenly distributed the distribution of test scores may have been greater, leading to more significant relationships between test scores and birth weight.

The next step was to compare mean differences between the LBW and NBW/ADHD groups on neuropsychological measures. Hypothesis 2 stated that children with LBW would demonstrate below average performance on a measure of visual motor integration (VMI) in comparison to norms and that standard scores on this test would be significantly lower than those of the NBW/ADHD group. Results of this analysis revealed no significant difference in scores on the test of visual motor integration between the LBW and NBW/ADHD groups. However, scores for both groups were in the low average range in comparison to norms. These results are consistent with other studies that have found that although children with LBW tend to have problems in visual spatial processing; no significant differences between children with LBW, VLBW, ELBW, and NBW were found when comparing mean scores on the VMI (Waber & McCormick, 1995). Low average performance in both groups may be related to the ADHD diagnosis, as 50% of the children in the LBW group carried a comorbid diagnosis of ADHD.

Hypothesis 3 stated that children with LBW would demonstrate below average performance on a measure of receptive language ability (PPVT) in comparison to norms and that standard scores on this test would be significantly lower that those of the
NBW/ADHD group. Again, no significant difference was found between standard scores on the PPVT between the two groups. However when compared to norms, mean standard scores were in the low average range for the LBW group and the average range for the NBW/ADHD. Low average performance on a measure of receptive language ability in children with LBW is consistent with results of studies conducted by Breslau et al. (1996b). However, previous studies comparing performance of children with and without ADHD on the PPVT, have revealed no significant differences between the two groups (Kim & Kaiser, 2000). Inconsistencies in results may be associated with the small sample sizes (11 children per group) in Kim and Kaiser’s (2000) study.

Hypothesis 4 stated that both children with LBW and children with NBW/ADHD would demonstrate below average performance on measures of attention (NEPSY), problem solving, set shifting and set maintenance (WCST). In addition, no significant difference in performance between the two groups was expected on these measures as there is a high comorbidity of ADHD in the LBW sample. As hypothesized, there was no significant difference between the groups on any of the WSCT and NEPSY measures between the LBW and the NBW/ADHD groups. Only the mean difference between the NEPSY visual attention subtest approached significance, with the LBW group demonstrating poorer performance than the NBW/ADHD group. When compared to norms, all mean scores on both the WCST and NEPSY measures were within the normal range with the exception of the scores on the NEPSY visual attention subtest, which was in the low average range for the LBW group and the auditory response set subtest, which was in the low average range for both groups.
Low average performance on WCST and NEPSY attention measures are consistent with other studies suggesting that children with ADHD show impaired performance on measures of attention and on the WCST (Seidman et al., 1997). Significantly poorer performance on a test of visual attention may reflect visual processing deficits, which have been consistently found in children with LBW (Picard et al., 2000).

Hypothesis 5 stated that children in the LBW group would demonstrate significantly poorer performance on memory subtests as compared to children in the NBW/ADHD group. Results of this analysis revealed significant difference between the two groups on the delayed recall index (DRI) and the nonverbal or visual memory composite (NM) of the TOMAL. In addition, the majority of the difference between DRI and NM composite scores may be accounted for by significant mean differences between the two groups on the delayed portion of the visual selective reminding subtest (VSR). On all three of TOMAL measures, the children in the LBW group demonstrated significantly poorer performance as compared to the children in the NBW/ADHD group. However, in comparison to norms, all mean scores on the TOMAL were within the average range, with the exception of the immediate recall scores on the Visual Selective Reminding subtest (VSR) which fell in the low average range for both groups. This is consistent with studies stating that children with LBW demonstrate below average performance in both tests of visual memory and in sequential memory (Levi-Shiff et al., 1995; Nadeau et al., 2001; Spreen et al., 1995). One study has shown that children with ADHD also demonstrate global below average performance in visual memory in comparison to norms as measured by the Learning Efficiency Test II (Killoran, 1997).
However, it has been suggested that memory deficits in children with ADHD are most likely associated with primary deficits in attention maintenance (Dewey et al., 2001). This suggests that the significantly poorer performance on the DRI, NM, and delayed VSR measures of the TOMAL by LBW subjects in comparison to subjects with NBW/ADHD may be unrelated to the high comorbidity of ADHD in the LBW sample.

Average performance on the verbal memory (VM) composite score of the TOMAL is inconsistent with studies that have found verbal memory deficits in children born with LBW (Taylor et al., 2000). However, Taylor et al. (2000) found significant differences only in a measure of verbal memory between children born with ELBW and children born with NBW. Due to the fact that only 11 of the 46 subjects in the LBW group fit into the ELBW category, there may not be enough power to detect verbal memory deficits with this sample.

Hypothesis 6 stated that for children in both LBW and ADHD groups, scaled scores on the measure of receptive language ability (PPVT) would be expected to be better as compared to scaled scores on the measure of visual motor integration (VMI). This is due to the fact that the visual system is the last of the sensory systems to develop. Therefore, children born with LBW tend to show below average performance on tasks involving the visual system (Picard et al., 2000). Results revealed that mean standard scores on the VMI were consistently lower than mean standard scores on the PPVT, however, this difference was not found to be significant for either group. Children in both the LBW and NBW/ADHD groups demonstrated below average performance on both the VMI and the PPVT. Poor performance in these domains may be related to shared cognitive difficulties between the two group, such as mental organization, and
processing of visual and verbally presented information. Higher scores on a measure of visual motor integration as compared to a measure of receptive language ability is consistent with the idea that children with LBW exhibit primary deficits in visual-spatial ability, which may be related to an underdeveloped visual system (Hack et al., 2000; Picard et al., 2000). The lack of a significant difference when performance on these measures is compared may be related to small sample size, and the positively skewed distribution of the LBW group.

Hypothesis 7 suggested that performance on the TOMAL across all subjects would be significantly predicted by birth weight after accounting for variance predicted by IQ, and scaled scores on the PPVT, the VMI, NEPSY visual and auditory attention subtests, and the WCST is. As noted by preliminary correlation analysis birth weight was found to have a significant positive relationship with only the TOMAL NM composite. As such, it is suggested that only variance in the TOMAL NM composite score can be predicted by birth weight. In addition, of the TOMAL subtest scores that make up the NM composite, only the delayed portion of the VSR subtest was found to have a significant positive correlation with birth weight. This suggests that the bulk of the relationship between NM and birth weight is best accounted for by performance on the delayed portion of the VSR subtest. Further, the only significant predictors of performance on the TOMAL NM composite score were found to be FSIQ, performance on the PPVT, and performance on the NEPSY visual attention subtest.

In order to determine whether birth weight significantly predicts variance in TOMAL NM composite scores after variance predicted by IQ, PPVT scores and NEPSY visual attention scores has been accounted for, a stepwise multiple regression analyses
was performed. As IQ and performance on the PPVT were found to be highly correlated, multiple regression analyses with PPVT scores and birth weight as predictors were run separately from analyses including IQ, NEPSY visual attention scores, and birth weight as predictors.

Results of the regression analysis revealed that increases in NM scores were significantly predicted by increases in IQ, PPVT scores, and NEPSY visual attention scores. This is inconsistent with previous studies which stated that the scores on measures of language, visual-spatial, fine motor, tactile, and attention skills tend to decrease with decreasing birth weight (Levi-Shiff et al., 1994; Picard et al., 2000). Therefore, it was predicted that scores on tests of memory would decrease with decreasing birth weight. Of interest is the positive correlation of birth weight with the NM composite of the TOMAL. Further, the majority of this relationship is associated with the positive correlation of birth with the TOMAL VSR task, which is a visual sequential memory task. These results are consistent with studies showing poor performance on measures on visual and sequential memory in children with born with LBW. However, our analysis indicated that birth weight does not predict a significant amount of variance in TOMAL NM scores after accounting for variance in IQ, receptive language, and visual attention abilities. This may be related to the paucity of subjects in the VLBW and ELBW ranges. It is likely that the relationship between birth weight and NM scores is more of a quadratic relationship, which would suggest that the variance in birth weight above 1500 g has less of an effect on memory scores than variance in birth weight below 1500 g or even 1000 g.
Study Limitations and Future Directions

There are a number of limitations of this study that may have played a significant role in the final results. First, the distribution of subjects in the LBW group is positively skewed. This is related to the fact that only a small percentage of the children in the LBW group were born weighing less than 1500 g. This suggests that results can be generalized for children weighing between 1500 and 2500 g but there is poor statistical power in the results to be generalized to children weighing less than 1500 g.

Related to poor statistical power, there are many trends observed in our analyses, however few significant differences have been found. This may be associated with relatively small sample size but is most likely related to poor sampling of children weighing less than 1500 g in the LBW group. Future analyses may focus on comparing performance of children born with LBW, VLBW, and ELBW on memory tasks.

The subjects in this analysis were matched for age. However, there may be a developmental progression or age-related effect of LBW that was not accounted for by this analysis. Longitudinal studies of the performance of children born with LBW have been conducted but analysis of performance on memory tasks has not been completed. Future studies may focus on comparing standard scores on memory tasks between different age groups.

An analysis of the contributory effects of biological risk factors and comorbid diagnosis was beyond the scope of this study. Previous research has indicated that children born with LBW are at a greater risk for medical conditions such as respiratory distress syndrome (RDS), bronchiopulmonary dysplasia (BPD), cerebral palsy, and intraventricular or periventricular hemorrhage (IVH/PVH; Picard et al., 2000). However,
there is a paucity of research focused on the contributory effect of these biological risk
factors to performance on neuropsychological tests. The majority of studies focus on the
effect of psychosocial variables such as maternal attitudes, personal status, paternal
environment, marital adjustment, and family climate on neuropsychological variables. A
number of the children in this study were afflicted with other medical conditions such as
asthma, RDS, BPD, allergies, and so forth. Future studies should focus on the
contributory effect of these associated medical conditions on neuropsychological
performance.

Most of the subjects in the LBW group carried at least one other comorbid
diagnosis of ADHD, LD, NLD, DD, SLD, FAS, or Hydrocephalus. Comorbid diagnosis
likely has a large impact on the child’s performance on neuropsychological measures.
Future studies should focus on the relative effect of comorbid diagnosis of children born
with LBW on neuropsychological variables.

Conclusions

Overall results are consistent with the hypothesis that children born with LBW
would demonstrate below average performance on tests of visual-motor integration,
receptive language ability, visual and auditory attention, problem solving, set shifting, set
maintenance, visual memory, and sequential memory. Inconsistent with proposed
hypotheses is the fact that no significant difference was found between children in the
LBW versus children in the NBW/ADHD groups on most measures. Except that children
in the LBW group demonstrated significantly poorer performance on measures of visual
attention, delayed recall, nonverbal/visual memory, and sequential memory. Of interest
is the fact that children with ADHD also demonstrated below average performance on
measures of visual motor integration, receptive language ability, auditory attention, and visual sequencing. It is suggested that the lack of the significant difference between the two groups is related to the fact that 50% of the children in the LBW group carry a comorbid diagnosis of ADHD. Therefore, common deficits in the two groups may be primarily related to the shared cognitive deficits between the two groups that is associated with the ADHD diagnosis.

Consistent with previous findings is that significant differences between the two groups were only found on tests related to the visual system. This provides further evidence for the hypothesis that children born with LBW have underdeveloped visual systems and therefore demonstrate primary deficits in visual tasks.

In addition, the hypothesis that performance on TOMAL scores would be significantly predicted by birth weight once variance predicted by other cognitive variables was accounted for was rejected. Only NM composite scores were significantly correlated with birth weight and results of regression analysis suggested that variance in NM composite scores was predicted primarily by IQ, and scores on measures of receptive language ability and visual attention.
REFERENCES


VITA AUCTORIS

Tammy Lyn Lorretta Whitlock was born on April 5\textsuperscript{th}, 1976 in Sudbury, Ontario.

Throughout her childhood she lived in Trenton, Ontario, Lahr, Germany and Ottawa, Ontario. In June 1995, she received her Ontario Secondary School Diploma from Brookfield High School in Ottawa, Ontario. In June 2000, she obtained a Bachelor of Science degree with highest honours in Neuroscience from Carleton University in Ottawa. She is currently a candidate for the Master of Arts degree in Clinical Neuropsychology at the University of Windsor and plans to graduate in the Fall 2002.