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The Relationship between Intellectual Ability and Memory in Children with Closed Head Injury.

By

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Abstract

The purpose of this study was to investigate the relationship between intellectual ability and memory impairment in children who have experienced a closed head injury. The 27 subjects were between the age of 9 - 18 years and had experienced a moderate or severe closed head injury. The children were given either the Wechsler Intelligence Scale for Children-Revised, the Wechsler Intelligence Scale for Children-III or the Wechsler Adult Intelligence Scale-Revised and the Logical Memory and Visual Reproduction subtests of the Wechsler Memory Scale-Revised. Significant differences were not found between the IQ scores and severity of injury, time since accident, age and gender. A significant main effect was only found for severity of injury and Logical Memory but not for Visual Reproduction. There is a relationship between IQ and memory, particularly Logical Memory. Some significant correlations were obtained for severity, time since accident, age and gender. The results were compared to the school aged normative database for the Wechsler Memory Scale-Revised. The information obtained could be useful in developing intervention programs or to aid in classroom placement.

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CHAPTER 1

INTRODUCTION

Statement of Problem

Until recently many children who experienced a traumatic brain injury would have died. Today there are many medical procedures available that allow children who have suffered this type of injury to survive, but their continued functioning is relatively unknown. A head injury refers to a traumatic insult to the brain that is capable of producing physical, intellectual, emotional and social changes within the person (Begali, 1992). Delayed effects on cognitive, emotional and psychosocial development are unique to childhood injuries (Lehr, 1990).

Most of the research on closed head injury focuses on adults. Begali (1992) reported on a study by the National Institute of Neurological Disorders and Stroke of the U.S. Department of Health and Human Services which found that the average head injury incidence rate was 200 per 100,000 people. Approximately 500,000-750,000 new cases will be admitted to hospital each year, with 30-50% of these injuries being classified as moderate, severe or fatal (Begali, 1992). Head injuries occur most frequently between the ages of 15-24 years and after the age of 70 years; and they are almost as frequent in the under 15 years age group as the 15-24 year old group (Goldstein & Levin, 1987). Males are twice as likely as females to sustain a head injury, and the injuries are generally more severe (Goldstein & Levin, 1987). Males also have a mortality rate 4 times higher than females (Annegers, 1983). Bigler (1990) reported that most head injuries are a result of motor vehicle, motorcycle and bicycle accidents. Head injuries can also result from falls, pedestrian injuries, assaults and child abuse, particularly from violent shaking (Bigler, 1990).

Bruce (1990) reported that the head injury incidence for the pediatric population is approximately 12,000 per 100,000 per year. Approximately 300,000-400,000 hospitalizations will occur. Michaud and Duhaime (1992) reported that for children from birth to 4 years of age the major cause of head injury are falls, motor vehicle accidents, sport or recreational activities and assault, which includes child abuse. For school aged children (5-9 years) falls, motor vehicle accidents and sport/recreational activities are the most frequent cause of head injury (Michaud & Duhaime, 1992). Children aged 10-14 years suffer from head injuries most frequently caused by motor vehicle accidents, falls and sports or recreational activities, while adolescents (15-19 years) suffer most head injuries either as the driver or passenger in a car (Michaud & Duhaime, 1992).

Information obtained from research on adults with closed head injury is relied upon when predicting the outcome for injured children and adolescents (Lehr, 1990). However, it may not be appropriate to use the information obtained from adults and apply it to children and adolescents, as they are not like adults in terms of brain function, organization and structure. The effects of head injury in children whose brains are still developing cannot be assumed to be the same as the effects in an adult's brain or even the same as a child at a different period of development (Lehr, 1990). It has been found that there is a direct relationship between injury severity and cognitive deficits with the more severe injuries related to more severe cognitive deficits (Levin, Goldstein, High & Eisenberg, 1988). Traumatic brain injury also has the potential to impair the capacity to learn and to consolidate new information (Lehr, 1990). In children, memory impairment is the most common cognitive deficit identified within 6 months following closed head injury (Ewing-Cobbs & Fletcher, 1987).

This study involves a sample of 27 children between the ages of 9 and 18 years with moderate or severe head injuries. The purpose of this study is to investigate the relationship between intellectual ability and memory functioning. Intellectual ability will be measured through the use of the Wechsler Intelligence scales and memory will be measured with the Logical Memory I, II and savings score and Visual Reproduction I, II and savings score subtests of the Wechsler Memory Scale-Revised (WMS-R). This sample will be compared to the norms in the Wechsler Intelligence scale manuals and to a normative database for the WMS-R subtest variables for children aged 9 through 15 years.

Research Questions for this Study

1. Is there a relationship between intelligence, measured by the Full Scale Intelligence Quotient and memory, measured by the WMS-R variables Logical Memory I, II and savings scores and Visual Reproduction I, II and savings scores? Does this relationship differ due to the severity of the injury, time since injury, age and gender of the child?
2. Is there a relationship between verbal intelligence, measured by the Verbal Intelligence Quotient and memory, measured by the WMS-R variables Logical Memory I, II and savings scores and Visual Reproduction I, II and savings scores? Does this relationship differ due to the severity of the injury, time since injury, age and gender of the child?
3. Is there a relationship between intelligence, measured by the Performance Intelligence Quotient and memory, measured by the WMS-R variables Logical o Memory I, II and savings scores and Visual Reproduction I, II and savings scores? Does this relationship differ due to the severity of the injury, time since injury, age and gender of the child?
4. Is there a difference between memory scores measured by the WMS-R variables and severity of injury and is there a difference between IQ scores and severity of injury?
5. Is there a difference between memory scores measured by the WMS-R variables and time since injury and is there a difference between IQ scores and time since injury?

6. Is there a difference between memory scores measured by the WMS-R variables and the age of the child and is there a difference between IQ scores and the age of the child?
7. Is there a difference between memory scores measured by the WMS-R variables and gender and is there a difference between IQ scores and gender?

A comparison will be made between the IQ scores and the WMS-R variables obtained by the closed head injured population and the school age normative database.

Delimitations and Limitations of the Study

This study is delimited by the decision to use the data from the Glenrose Rehabilitation Hospital. This study is also limited by several factors. The subjects for the clinical sample were patients at the Glenrose Rehabilitation Hospital. The sample was limited by the criteria imposed by the pediatric brain injury program at the Glenrose Rehabilitation Hospital and the criteria imposed for the purpose of this study. The subjects from the normative database were from one Edmonton, Alberta, public school system.

The sample size for this study is small, limiting the generalizability of the findings to other head injury populations.

Overview of the Study

Chapter 2 of this thesis contains a literature review of research in the areas of classification and impairments due to closed head injury. It also includes a review of the literature concerning the Wechsler scales and intelligence testing in a head injured population, a model of memory and a discussion of memory development in childhood, and memory assessment in a head injured population. It concludes with a survey of literature linking head injury, intelligence, and memory. Chapter 3 includes a description of the methodology. The results of this study are presented in Chapter 4. Chapter 5 includes a discussion of the findings, implications of the study, and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

The review of the literature presented in this chapter will cover four main areas. The first area discussed will be impairments due to head injury, followed by a discussion of intelligence and intelligence testing. Then a model of memory and the development of memory in childhood will be presented. The last area will include a review of studies that have focused on the areas of memory and intelligence in adults and children who have experienced closed head injuries.

Classification of Head Injuries

Head injuries are classified as either open or closed. In an open head injury the scalp is lacerated, and the skull is penetrated by an intruding object such as a bullet or fragments of bone from the skull (Orsini, Van Gorp, & Boone, 1988). An open head injury is somewhat predictable because the resulting sequelae are due to localization and the degree of damage (Blosser & DePompei, 1994). A closed head injury (CHI) can be caused by either a blow to the head with a blunt object, a rapid acceleration and subsequent deceleration of the head (Orsini et al., 1988). These actions can cause a linear or rotational movement of the brain against the hard, bony inner surface of the skull, resulting in diffuse damage (Blosser & DePompei, 1994).

Head injuries include both primary and secondary damage. Primary damage occurs at the time of the accident and is a direct result of forces acting on the brain (Mira, Tucker & Tyler, 1992). It is this damage that will be irreversible and will be the source of many long-term deficits (Mira et al., 1992). An example of primary damage in a closed head injury is a coup and contre coup injury. The coup contusion occurs when the brain is thrust against the skull initially bruising of the brain at the point of impact. When the brain is thrust against the opposite side of the skull, a contre coup contusion occurs (Orsini, Van Gorp, & Boone, 1988). Contre coup effects are very common and occur in 50-80% of the cases (Orsini et al., 1988). Diffuse axonal injury causes widespread damage and is due to the twisting of the brain, which forces tissues together and then pulls them apart, resulting in the tearing or shearing of axonal fibers (Blosser & DePompei, 1994). It is an example of primary damage.

Secondary brain damage occurs shortly after the initial impact and is due to a variety of potentially preventable and reversible causes (Currie, 1993). Edema or swelling of the brain leads to an increase in intracranial pressure which can cause compression of brain tissue and lead to a loss of consciousness (Blosser & DePompei, 1994). Snoek (1990) found that the swelling may be generalized or confined to one hemisphere. Hypoxia is caused by a decreased supply of oxygen to the brain due to a disruption in blood flow (Blosser & DePompei, 1994). Hematomas are caused by bleeding in the brain, which creates a clot that fills the ventricles within the skull, thus exerting pressure on brain tissue (Orsini, Van Gorp, & Boone, 1988).

Closed head injuries often give rise to a period of unconsciousness, which can be brief (a matter of seconds or minutes) or prolonged. A prolonged loss of consciousness is referred to as a coma, during which a person fails to respond either verbally or motorically to simple verbal commands (Levin & Eisenberg, 1979). The depth of a coma is measured by the Glasgow Coma Scale (GCS). Two commonly used criteria to classify the severity of a closed or open head injury are the GCS and the duration of post-traumatic amnesia (PTA). The GCS is used to evaluate the components of wakefulness, which include eye opening in response to a stimulus, motor response and verbal response (Begali, 1992). Motor response includes obeying commands and localizing reflexes, while verbal response includes orientation and the use of speech (Richardson, 1990). The GCS is measured on a 15 point scale. Scores of 0-8 indicate that a person is comatose and has suffered a severe injury; scores of 9-11 indicate that a person has experienced a loss of consciousness and has suffered a moderate injury; and scores of 12-15 indicate that a person has had little or no loss of consciousness and has suffered a mild injury (Bond, 1986).

Post-traumatic amnesia (PTA) is the interval of time between the injury, including the coma length and the regaining of continuous day to day memory (Jennett & Teasdale, 1981). Mental disorientation is the inability to orient to time, place and self (Richardson, 1990). PTA lasts for minutes, hours, days or weeks. PTA is generally considered to be approximately 4 times longer than the interval of time before the person speaks, unless the person is unable to speak for a specific reason (Jennett & Teasdale, 1981). For the purpose of this study a scale originally proposed by Russell to show correlation between PTA and severity of injury will be used. PTA of less than 5 minutes indicates a very mild injury and a PTA of 5-60 minutes indicates a mild injury, while a moderate injury has a PTA of 1-24 hours (Jennett & Teasdale, 1981). A severe injury has a PTA of 1-7 days, a very severe injury has a PTA of 1-4 weeks and an extremely severe injury has a PTA of more than 4 weeks (Jennett & Teasdale, 1981).

This study focuses on moderate and severe injuries. A moderate head injury will have a GCS score of 9-11, a loss of consciousness up to 24 hours and a PTA of 1-24 hours. All severe injuries will have a GCS score of 0-8 and a loss of consciousness of more than 24 hours. Depending on the severity of the severe head injury, PTA will range from 1 day to more than 4 weeks. For this study mild head injuries have been excluded.

Impairment Due to Head Injury

The brain controls all of the body's actions and functions including digestion, temperature, breathing, heart rate and blood pressure. It receives and interprets messages from sense organs and allows the body to respond, move or react to the environment. When the brain is injured, the person can experience both physical and cognitive problems. Brain injury affects adaptability to the environment, acquisition of knowledge and judgement.

Children differ from adults in terms of the effects experienced due to a closed head injury. Children may show little change in neurological functioning despite severe injury, only to deteriorate quickly (Lehr, 1990). Cerebral swelling is a more frequent occurrence in childhood, while bleeding in the brain and seizure disorders occur less frequently in childhood as a result of a closed head injury. Lehr (1990) reported that there is growing evidence that children exhibit more severe and acute neurological dysfunction and may need less impact at time of injury to cause similar neurological effects as in adults. Children often have a more favourable prognosis despite poor neurological condition after injury (Lehr, 1990).

The effect of the brain damage depends on the time since injury and the age of the person at the time that the injury occurs. There are different patterns of recovery and compensation between adults and the developing child (Parker, 1990). An adult has already developed a large knowledge base of learned skills, while a child has yet to obtain this knowledge (Mira, Tucker, & Tyler, 1992). Children have less accumulated knowledge and skills to rely on post brain injury, and brain injury has been shown to affect the acquisition of new skills (Parker, 1990). A child over the age of 2 years usually has a brain and skull base that resembles that of an adult but the organ is still in the process of maturing (Parker, 1990). At around the age of 20 years the brain stops maturing both anatomically and physiologically (Parker, 1990).

Brain injury in adults and children can be both different and similar. Similar patterns of deficits can arise in children and adults with different injuries and different patterns of deficits can arise in children and adults with similar injuries (Lehr, 1990). Deficits may be apparent soon after injury. Deficits often disappear later in children because the part of the brain that is damaged is often compensated for by other parts of the brain (Lehr, 1990). Some deficits do not appear until well after the injury.

This occurs because the part of the brain that was damaged may not have matured enough to be functioning at the time of the accident, and the deficit is noticed only later when the child does not progress beyond a certain point, or when a particular skill such as writing does not appear when expected (Lehr, 1990).

It is an erroneous belief that children are more able to tolerate and recover from a head injury than adults as a child's developing brain is especially vulnerable to damage (Currie, 1993). A child's brain, however, does have the advantage of cerebral plasticity. For example, children who have experienced left hemisphere damage often have language functions that are intact, possibly because the language abilities have moved to the right hemisphere. This shift occurs at the expense of visuospatial functions that are located in the right hemisphere (Kolb & Whishaw, 1990). Restitution refers to the brain's capacity to reorganize itself after injury so that it is able to achieve the same goals the same way (Goodman, 1989). Substition refers to the acquisition of alternative strategies to achieve the goals in different ways (Goodman, 1989).

There are limits to the amount of recovery due to cerebral plasticity. The location of the brain injury can affect recovery. If both sides of the brain are damaged there is little chance that brain reorganization will reconstruct the damaged function elsewhere in the brain, but if only one side of the brain is injured, chances of recovery are better (Goodman, 1989). Sometimes the new connections that are created interfere with recovery and this can lead to poor concentration, hyperactivity, learning problems, and lowered IQ (Goodman, 1989). The benefits of cerebral plasticity are often exaggerated as children usually are left with subtle residual deficits that can lead to intellectual, educational, and behavioral difficulties (Goodman, 1989).

Intelligence

There are many different theories and definitions of intelligence. David Wechsler defined intelligence as a global entity rather than a unique capacity, which involves affective and conative as well as cognitive components (Wechsler, 1939). Intelligence is the global capacity of the individual to act purposefully, to think rationally and to deal effectively with the environment (Matarazzo, 1976). The Wechsler scales were designed to test the individuals' capacity to utilize their cognitive abilities towards the type of problem solving and reasoning required to complete the tasks. Wechsler believed that the person's performance on an intelligence test would reflect cognitive impairments (Frank, 1983).

The development of the Wechsler scales was greatly influenced by the work of Binet. Many of the Verbal subtests and some of the Performance subtests items closely resemble Binet items (Kaufman, 1979). Both the Binet and Wechsler scales have their roots in the nonverbal test batteries that were used about half a century ago (Kaufman, 1979). With the publication of the Wechsler-Bellevue Intelligence Scale in 1939, Wechsler stated that his aim was not to produce a new test but to select items from available sources to meet the requirements of an effective adult scale (Wechsler, 1939). Many items for all subtests were selected from the Yoakum and Yerkes Army Alpha Test and Army Beta Test (1920), and Whipple's National Intelligence Tests

(1921) as well as from the work of others such as Binet, Terman and Chamberlain, Pitner and Patterson, Thorndike and Manson (Frank, 1983). Using the same principles and many of the same items, Wechsler published the Wechsler Adult Intelligence Scale (WAIS) in 1955 and its revision, the Wechsler Adult Intelligence Scale-Revised (WAIS-R) in 1981 (Wechsler, 1981). The Wechsler Intelligence Scale for Children (WISC) was published in 1949, the Wechsler Intelligence Scale for Children-Revised (WISC-R) was published in 1974 and the Wechsler Intelligence Scale for Children-111 was published in 1991. These are all descendants of the Wechsler-Bellevue Scale (Wechsler, 1991). The WAIS and WAIS-R are used to measure intelligence of adults between the ages of 16 and 74 years, while the WISC-R and WISC-111 are used to measure intellectual ability of children between the ages of 6 years and 16 years 11 months.

Wechsler's scales reflect Cattell-Horn theory of fluid and crystallized intelligence. The Verbal scale excluding Digit Span is a good measure of crystallized intelligence and the Performance scale is a good measure of fluid intelligence (Kaufman, 1979). Crystallized intelligence reflects material normally taught in school and manifests itself in the ability tests of vocabulary, numerical skills, memory and logical reasoning (Matarazzo, 1976). Crystallized ability continues to grow until the age of 40 years and possibly beyond that time (Matarazzo, 1976). Fluid intelligence, which involves reasoning and problem solving, is nonverbal and relatively independent of the effects of culture, education and experience (Matarazzo, 1976). It continues to develop until the age of 14 years and later begins to decline due to brain damage, brain disease and the normal aging process of adulthood (Matarazzo, 1976). Fluid intelligence is thought to be sensitive to the extent of brain damage because it is a measure of adaptation and flexibility when the individual is faced with unfamiliar stimuli and is gained through incidental learning (Kaufman, 1979).

The Wechsler Scales

The Wechsler scales contain two scales, Verbal and Performance. The scales follow a similar format. The Verbal Scale consists of six subtests and the Performance Scale consists of four subtests that are common to all three scales. Each subtest results in both a raw and scaled score.

The Verbal scale measures a person's ability to use and think with words and process verbal information. The subtests for this scale are Information, Similarities, Vocabulary, Comprehension, Arithmetic and Digit Span. These subtests with the exception of Digit Span are added together to obtain the Verbal IQ (VIQ) score. The Performance Scale measures the person's ability to use nonverbal reasoning and visual spatial skills. The subtests for this scale are Picture Completion, Picture Arrangement, Block Design and Object Assembly. The WISC-R and WISC-111 both contain the subtests Coding and Mazes but the WISC-111 also contains the subtest Symbol Search. Either Coding or Mazes is given depending on the age of the child. The WAIS-R uses Digit Symbol as a replacement for the Coding and Mazes subtests. The subtests, with the exception of Digit Symbol, Symbol Search and Mazes are added together to obtain a Performance IQ (PIQ) score.

The IQ scores obtained by the WISC-R and WISC-111 are similar. The Full Scale IQ (FSIQ) is determined by adding together the scaled scores for the VIQ and PIQ. The WISC-111 FSIQ is approximately 5 points less than the WISC-R FSIQ (Wechsler, 1991). The WISC-111 VIQ is approximately 2 points less and the WISC-111 PIQ is approximately 7 points less than the scores on the WISC-R (Wechsler, 1991). In a study by Sabantino, Spangler and Vance (1995) it was found that in a gifted population the FSIQ, VIQ and PIQ are highly similar on the WISC-R and the WISC-111. The difference between the VIQ and PIQ scores were 2 points and less than 1 point on the FSIQ. Sattler (1992) reported that for a group of 104 children who had reading difficulties and Attention Deficit Hyperactivity Disorder the FSIQ on the WISC-111 was 5.9 points above that of the WISC-R. On VIQ and PIQ the scores were 5.4 and 5.1 points lower respectively for the WISC-111. The WAIS-R results in IQ scores that are slightly greater than those obtained by the WISC-111. The WAIS-R FSIQ is about 4 points greater, the WAIS-R VIQ is approximately 2 points greater and the WAIS-R PIQ is approximately 6 points greater than those scores obtained on the WISC-111 (Wechsler, 1991). The IQ scores obtained on the WAIS-R and WISC-R are very similar for the 16 year old group. The Iqs differ by 0 points on VIQ, 2 points on PIQ and 1 point on the FSIQ, with the WISC-R yielding the higher score (Wechsler, 1981). In a study involving 30 learning disabled adolescents aged 16 years, the scores obtained on the WISC-R and WAIS-R were also very similar. The FSIQ and VIQ differed by 1 point and the PIQ differed by 3 points (Sandoval, Sassenrath & Penaloza, 1988).

Strengths and Weaknesses of the Wechsler Scales

Intelligence tests are presently the best instruments available for determining an individual's mental functioning. The Wechsler scales are a measure of what a person has learned. It is a measure of the person's past accomplishments and is predictive of success in traditional school subjects (Kaufman, 1979). There is a reasonable amount of overlap between the abilities measured by IQ scores and the abilities that are supported by the various theories of intelligence (Kaufman, 1979). If test users are careful in how they facilitate test interpretation, and in selecting supplementary measures and understand the limitations of IQ testing then the tests can be used in an effective manner. The IQ scores can provide useful information about a person's cognitive strengths and weaknesses whether it is a neuropsychological, clinical or psychoeducational assessment.

Kaufman (1979) notes that intelligence tests have received a lot of criticism over the years. One of the main criticisms of the Wechsler scales is that there have been many advances in the areas of cognitive development, learning theory and neuropsychology during the last 25-50 years that have not been reflected in the structure of the test mainly in the area of item content (Kaufman, 1979). Wechsler (1991) noted that 73% of the WISC-R items were retained either unchanged or changed slightly on the WISC-111. The WAIS-R contains 80% of the items from the WAIS (Wechsler, 1981).

The other main criticism of intelligence tests is the emphasis placed on the unfair educational consequences that result from the misuse or abuse of the results.

Intelligence tests are used to predict the ability to learn in school. The WISC-R IQ scores have a moderate to good correlation with achievement tests. Wechsler (1991) reported total achievement and WISC-111 correlations as 0.74, 0.57 and 0.74 for VIQ, PIQ and FSIQ respectively. Often supporters of intelligence testing perceive IQ scores as immutable reflections of the child's ability and use this information to place a child academically (Kaufman, 1979). IQ tests should only be taken as the best estimate of a child's current intellectual abilities.

The Use of the Wechsler Scales with a Head Injured Population

The Wechsler scales were not intended to be neuropsychological tests but to provide useful information when used in conjunction with other neuropsychological tests (Wechsler, 1991). Moore et al. (1990) investigated the test-retest stability of the WAIS-R in a head injured population with a mean age of 27.02 years with a mean test-retest interval of 8.48 months. Upon retesting the FSIQ increased by 6 points, the VIQ increased by 4 points, and the PIQ increased by 8 points (Moore et al., 1990). Digit Symbol scores were the lowest, which is consistent with the knowledge that this subscale is the most sensitive to brain damage (Moore et al., 1990). The researchers concluded that the test-retest reliability of the WAIS-R is relatively good for the head injured population (Moore et al., 1990). It is unclear if the results are due to the range of test-retest intervals or due to the cognitive recovery that occurs after brain damage (Moore et al., 1990). It may be difficult to generalize the results of this study to the general head injured population, as the severity of the injury has not been mentioned.

Chadwick, Rutter, Thompson and Shaffer (1981) concluded that severe generalized brain trauma decreases intellectual levels. It was found that children who had a loss of consciousness of 72 hours or more had an IQ that was 8.5 points lower than less severely injured children and those who had evidence of cerebral edema had an IQ that was 7.5 points lower (Chadwick, Rutter, Thompson, et al., 1981). Intellectual impairment most frequently occurs following generalized damage, but may also be found as a result of severe localized damage (Chadwick, Rutter, Thompson, et al., 1981). Head injury impairs the acquisition of new skills rather than the loss of well established old skills, as evidenced on the tests of scholastic achievement (Chadwick, Rutter, Thompson, et al., 1981).

Levin and Eisenberg (1979) studied 64 children and adolescents who had suffered a closed head injury. It was concluded that intellectual level had returned to within normal limits for all but the most severe injuries within 6 months post injury (Levin & Eisenberg, 1979). When compared to estimates of premorbid ability it appears as though only partial intellectual recovery was achieved (Levin & Eisenberg, 1979). The most severely injured had a coma lasting greater than 24 hours and 42% of the subjects had an abnormal CT scan that revealed the presence of a haematoma or focal edema (Levin & Eisenberg, 1979).

Chadwick, Rutter, Brown, Shaffer and Traub (1981) compared severe head injured children to those with mild head injuries and to a control group of children who were hospitalized for an orthopaedic injury. The children were assessed with a short form of the WISC when the child recovered from PTA, at 4 months, 1 year and at 2 1/4 years after injury. A prorated VIQ was calculated initially and again at 1 year, while a prorated PIQ was calculated at all assessments. The control group's score increased with each assessment. Between the initial assessment and the 1 year assessment the mean PIQ increased 6.8 points, and then between 1 year and 2 1/4 years it increased another 2.6 points (Chadwick, Rutter, Brown, et al., 1981). The mild head injured group's PIQ remained relatively constant with an 8.6 point deficit at initial assessment, 10 points at 1 year and 9.4 points at 2 1/4 years (Chadwick, Rutter, Brown, et al., 1981). Those children with severe closed head injures showed the most change over time. At the initial assessment the deficit was 30.2 points, at 1 year 11.5 points and at 2 1/4 years 12.0 points (Chadwick, Rutter, Brown, et al., 1981). It was also noted that much of the cognitive recovery had already taken place at 4 months post injury for the children in the severe group (Chadwick, Rutter, Brown, et al., 1981).

The control group and the mild head injured group had mean V-P IQ differences that were small for all assessments (Chadwick, Rutter, Brown, et al., 1981). Children with severe head injuries had a VIQ that exceeded PIQ by an amount that was significantly greater than that obtained by the controls (Chadwick, Rutter, Brown, et al., 1981). Less than 5% of the control group had a V-P IQ discrepancy with PIQ being at least 25 points lower than VIQ, while 33% of the severe head injured group had this type of discrepancy at the initial assessment and only 6% showed this pattern at the 1 year assessment (Chadwick, Rutter, Brown, et al., 1981). Chadwick, Rutter, Brown, et al (1981) concluded at the 1 year assessment that the V-P IQ discrepancy favouring VIQ was not more common in a head injured population than in the general population.

Chadwick, Rutter, Brown, et al. (1981) concluded that if PTA was more than 3 weeks intellectual deficits were common and maybe permanent. If PTA was in the 2-3 week range, persistent impairment was less common but transient impairment was fairly frequent (Chadwick, Rutter, Brown, et al., 1981). The severity of the injury affected the degree and persistence of the intellectual impairment as well as the speed and the extent of the recovery (Chadwick, Rutter, Brown, et al. 1981). These results suggest that a child who has had a head injury should be assessed more than once in order to determine the extent of the impairment.

Memory

Memory is an important part of everyday life. Memory is used to perform the simplest and most familiar behaviours such as tying our shoes or recalling phone numbers, and the more complex behaviours, such as driving a car or preparing a meal (Goethals & Soloman, 1989). Memory refers to three different kinds of mental activities: initial acquisition of information (learning), subsequent retention of the information and retrieval of the information.

Information Processing Theory

In the early 1970's Craik and Lockhart proposed a level of processing model for memory that is referred to as the depth of processing approach. Craik and Lockhart assumed that there is only one memory store (Searleman & Herrman, 1994). Memory depends on the method used to process the information.

Type I processing is used to maintain information in the primary memory (Craik & Lockhart, 1972). Incoming stimuli can be processed at a superficial level where physical or sensory features are a concern (Criak & Lockhart, 1972). This type of processing keeps the information accessible but does not allow the information to be stored permanently. It is during this type of processing that information can be lost. Type II processing allows the information to be processed more elaborately and to a deeper level where the semantic properties of a stimulus are analyzed (Craik & Lockhart, 1972). At this level information is maintained because it is elaborated on and relationships are formed between the new information and information that has been previously stored in memory. Type II processing requires that more attention and effort be made during the encoding process (Ashcraft, 1989). Ashcraft (1989) provided an example of Type I processing as repeating a phone number in order to keep in conscious awareness and an example of Type II processing would be if that phone number is related to something meaningful then it will be remembered in the future.

The notion of a generation effect supports the levels of processing approach. This means that items that are self-generated are better remembered. Searleman and Herrman (1994) noted that students who paraphrase what they are studying benefit from a deeper level of processing because the material has been self-generated. This effect has been observed in tasks involving free recall, cued recall and recognition tasks. Searleman and Herrman (1994) stated that the generation effect can also be seen in situations involving incidental and intentional learning situations.

In a study by Rogers, Kuiper and Kirker (1977) subjects were asked to make judgements on adjectives based on their semantic meanings, physical appearance, and phonemic characteristics. The subjects were also asked to decide if the words described themselves. During a surprise free recall test the subjects had better recall for words they thought described themselves. Searleman and Herrman (1994) stated that if a person decides that the word describes oneself then it results in a deeper level of encoding. This is known as the self-reference effect.

The levels of processing approach also received some criticism. Searleman and Herrman (1994) reported that there was no adequate way to independently measure the depth of processing separately from the amount of retention. This leads to a circulatory problem. If information is well remembered it is because it was encoded deeply. However, there is no way of determining how deeply it was encoded without examining how well it was retained. Craik (1990) argues that the circulatory issue is not that serious a problem. There is excellent agreement among independent judges as to what types of processing are deeper than others. Other concepts in psychology such as reinforcement have been accepted even though they can not be measured independently (Searleman & Herrman, 1994).

Another criticism of the levels of processing approach involves maintenance rehearsal and long term retention. Only elaborative rehearsal is supposed to lead to long-term retention. Searleman and Herrman (1994) cited studies by Glenberg and Adams (1978), Glenberg, Smith and Green (1977), Mechanic (1964), Naire (1983), Nelson (1977) and Woodward, Bjork and Jongeward (1973) which found that maintenance rehearsal can lead to long-term retention.

A third criticism concerns the premise that superficially encoded material will not be remembered as well as information that is processed deeply. Morris, Bransford and Franks (1977) found that shallower processing measured by rhyming did not necessarily lead to poorer retention. Superficial as well as semantic information played a role in remembering. Transfer appropriate processing stressed that the value of particular acquisition activities must be defined relative to particular goals and purposes (Morris et al., 1977). Morris et al. found that acquisition tasks are not superficial if they are meaningful to a particular person or to a particular learning task. Searleman and Herrman (1994) summarized that transfer appropriate processing and the levels of processing approach could coexist without negating each other. The transfer appropriate processing model emphasizes that encoding and retrieval processes are closely tied.

Development of Memory in Children

Piaget's theory of cognitive development spans birth to adolescence dividing this period into four stages; the sensorimotor (birth to 2 years); the preoperational (2-7 years); the concrete operational (7-11 years) and the formal operational (11-18 years). These stages of development also include the development of memory.

The study of memory during the sensorimotor period is difficult because memory cannot be tested in the most prevalent way, ie. through the use of verbal instructions and responses. The most common method to assess infant memory has been the habituation-dishabituation paradigm. In this paradigm habituation would be observed by a decrease in looking at the stimulus, while dishabituation would be observed by an increase in looking at the stimulus to habituation levels. By the time infants are 6 months old, they can recognize visual stimuli after a 2 week delay and visual memory is thought to develop quickly between 6-12 months (Searleman & Herrman, 1994).

During the preoperational period, a child's ability to perform memory tasks improves dramatically. Recognition memory continues to develop. Recognition memory is the ability to realize that the object has been encountered before. Clarke-Stewart, Friedman and Koch (1985) reported that it was found that 2 year olds were able to recognize 81% of the original objects and that 4 year olds were able to recognize 92% of the objects.

Recall memory involves the retrieval of information from memory without prompts from the environment (Clarke-Stewart, Friedman & Koch, 1985). It is a more difficult process. Recall memory is tested by showing a child some objects and then removing them from view and asking the child what objects they were presented. Even when told they could keep the objects they recalled, 3 year olds remembered only 2 of the 9 objects and 4 year olds remembered 3 or 4 objects (Perlmutter & Myers, 1979 cited in Clarke-Stewart et al., 1985). Most children were able to recall more objects if prompted with a clue.

In the concrete operational stage (ages 7-11 years) the child begins to develop mnemonic strategies such as rehearsal, chunking and clustering. Rehearsal involves repeating information to help maintain it in short-term memory. Spontaneous rehearsal of information begins at about 5 years of age and the ability to use rehearsal improves with age. Steuer (1994) cited a study by Flavell, Beach and Chinsky (1966) in which it was found that only about 10% of 5 year olds, 60% of 7 year olds and 85% of 10 year olds used rehearsal.

Clustering is a method used to help facilitate memory transfers from short-term to long-term memory. It involves grouping items by category, which are easier to remember than nonclustered items (Steuer, 1994). The process in which material is broken into smaller pieces is known as chunking. Chunks may contain different amounts of information. An example of chunking as a method of remembering is a grocery list. The chunk "deserts" could include ice cream, cookies and peaches (Clarke-Stewart, Friedman & Koch, 1985).

During the formal operation period (ages 11-18 years) processing speed continues to increase and mnemonic strategies such as rehearsal continue to develop (Searleman & Herrman, 1994). Adolescents begin to use elaboration as a memory strategy. Adolescents are able to associate two or more unrelated items in order to remember them (Clarke-Stewart, Friedman & Koch, 1985). An example of an elaboration is "In fourteen hundred ninety-two, Columbus sailed the ocean blue" (Clarke-Stewart, et al., 1985, p. 368).

Memory development has been shown to begin during infancy and continue to develop throughout childhood, into adolescence and into adulthood. Brain injury will alter the development of memory or the use of memory strategies. Memory impairment is one of the most common cognitive deficits after pediatric or adult traumatic brain injury. Impairment can occur in all areas of memory including visual and verbal memory. One measure that is used to asses these areas of memory is the Wechsler Memory Scale-Revised.

Wechsler Memory Scale - Revised (WMS-R)

The WMS-R (1987) is a revision of the Wechsler Memory Scale (WMS). It is an individually administered clinical instrument that is used as a diagnostic and screening device to assess memory functions in adolescents and adults (Wechsler, 1987). The WMS-R was developed to better address aspects of memory that are considered to be clinically significant and as an attempt to improve on several areas of the WMS. The WMS-R manual reports that the revisions included the provision of norms stratified at nine age levels and the single global summary score, the Memory Quotient, was replaced with five composite scores. New subtests measuring figural and spatial memory were added as well as measures of delayed recall. The last change included the revision of scoring procedures on several subtests to improve scoring accuracy.

The WMS-R is comprised of eight subtests that measure different aspects of memory. It was designed to measure memory for verbal and figural stimuli, meaningful and abstract material, as well as delayed and immediate recall (Wechsler, 1987). Wechsler (1987) warns that caution should be used when interpreting results from non-native English speakers and those outside the age range of the test. The "scale is also not suitable for making fine discriminations at high levels of memory functioning" (p. 7).

Bowden and Bell (1992) concluded that the WMS-R did overcome the short-comings of the WMS. The improvements in the scoring criteria and administration should permit a more valid assessment of memory even when much of the same stimulus materials are used. The WMS-R provides a more sensitive general memory assessment and is likely to be more sensitive to change in true scores over time (Bowden & Bell, 1992).

The WMS-R manual provides information on 14 studies that examined the validity of the test in discriminating between clinical and normal populations. The diagnoses of the 14 clinical groups were alcoholism, Alzheimer's disease, brain cancer, closed head injury, dementia, depression, Huntington's disease, Korsakoff's syndrome, multiple sclerosis, psychiatric groups, schizophrenia, seizure disorder, stroke and neurotoxins. Wechsler (1987) found that the clinical groups scored significantly lower than the normal population on all indexes. This pattern provided evidence of criterion-related validity. The data from these clinical groups is not meant to be representative of the different clinical groups but to be suggestive of their performance. The studies did not control for factors such as length and severity of illness which may affect the WMS-R scores. Wechsler (1987) concluded that the "data do support the utility of the WMS-R in assessing memory impairment" (p. 86).

Memory deficits that occur with closed head injuries manifest themselves in varying degrees of verbal and visual impairments (Reid & Kelly, 1993). A study by Reid and Kelly (1993) was designed to assess the validity of the WMS-R in a group of patients with a relatively recent injury. Closed head injured patients performed more poorly on all 5 indices and particularly on the Logical Memory and Visual Reproduction subtests of the WMS-R compared to their age and education level matched normal controls. The WMS-R scores did not correlate to either PTA or GCS as a measure of severity. Reid and Kelly (1993) found that the normal controls retained more information than the head injured group on the Logical Memory Savings Score and Visual Reproduction Savings Score. It was concluded that the WMS-R does provide a valid assessment of memory impairment in closed head injured patients. The WMS-R was able to significantly discriminate between the performance of a group of normal control subjects and a group of head injured patients.

Miller, Paniak and Murphy (1993) collected normative data on the WMS-R for children aged 9-15 years. Lee (1995) used this data and found that the scores for the subtests Logical Memory and Visual Reproduction increase with increased age with the exception of the Logical Memory Savings Score in which age did not have a significant effect. When these norms are compared to those of a pediatric closed head injured population, the head injured group scored significantly lower than the normal control group (Lee, 1995). The clinical group performed significantly lower than a control group, matched for age and gender, on tests of immediate and delayed recall of verbal information and delayed recall on visual material. The head injured subjects did not differ significantly from normal subjects on the ability to immediately recall visual material (Lee, 1995). The Logical Memory and Visual Reproduction Savings Scores were able to discriminate between the clinical and control groups' performance

(Lee, 1995).

Memory Research and Pediatric Closed Head Injury

Memory research on adults with head injuries utilizes the WMS-R. The WMS-R manual does not have published norms for children under the age of 16 years, therefore, the memory research presented with children will involve the use of other memory tests. The tests typically used in pediatric research are the California Verbal Learning Tests-Children's version (CVLT-C) which measures short and long term memory and recognition memory, and the Denman Neuropsychology Memory Scale (Denman) which measures immediate and delayed recall of verbal and nonverbal information. The Selective Reminding Test (SRT) assesses verbal memory, and the Continuous Recognition Memory Test is a visual memory test that evaluates the child's discrimination between old stimuli and new stimuli.

A series of longitudinal studies measured memory impairment experienced as a result of the severity of injury. Children in the sample were between the ages of 6 and 15 years and contained mild, moderate and severe head injuries. The clinical population was matched by age, gender and school grade to a normal control population. At 1 month post injury the CVLT-C showed that there was a consistent decline in absolute scores with increasing levels of severity for all 5 memory subtests (Jaffe et al., 1992). At 1 year post injury severity of injury was significantly associated with both long-term free and cued recall and was not significantly associated with short-term memory and long-term recognition subtests (Jaffe et al., 1993). Fay et al. (1994) found that at 3 years post injury, moderately and severely injured children had a lower performance level on all subtests of the CVLT-C. The more severely injured children remembered fewer words in free or cued recall and in recognition tasks for short or long-term memory.

Donders (1993) conducted a study of children ages 10-16 years, who had experienced a mild, moderate or severe traumatic brain injury and were less than 1 year post injury. It was found by using the Denman that the proportion of verbal information lost between immediate and delayed recall did not differ for mild/moderate and severe groups. Both mild/moderate and severe groups had poorer delayed recall than immediate recall for verbal material but this was not the case for nonverbal material (Donders, 1993). Subjects in the mild/moderate group tended to have better recall of nonverbal material but not verbal material than the severe group (Doders, 1993). It is difficult to compare the results of this study to other research on traumatic brain injury because it does not mention the type of brain injuries involved.

Levin, Eisenberg, Wigg and Kobayashi (1982) conducted a study that compared memory as measured by the SRT, for children under 12 years of age and adolescents (aged 13-19 years) who had been matched for severity. Children with a severe head injury (GCS≤8) entered fewer words into long-term memory and were less efficient at retrieving the words than children who had less severe injuries (GCS≥8). Adolescents who had GCS≤8 had significantly impaired long term store and retrieval than adolescents who were less severely injured. Both children and adolescents who had a GCS≤8 had impaired retrieval at 1 year. Children, but not adolescents, with severe closed head injuries showed residual deficits in visual recognition memory as measured by the Continuous Recognition Memory Test than children with milder head injuries (Levin et al., 1982).

In a study of children and adolescents who have suffered a closed head injury it was found that severe injuries (GCS≤8) generally produced a memory impairment that persisted 1 year and that within 1 year of obtaining a mild to moderate closed head injury memory recovered to an age appropriate level (Levin, High et al., 1988). Children and adolescents with severe injuries obtained lower visual memory scores than children and adolescents with mild/moderate injuries at both the baseline and 1 year post injury. Visual recognition memory improved, irrespective of severity of injury and age from the baseline to 1 year post injury (Levin, High et al., 1988). Severely injured children and adolescents obtained lower verbal memory scores on the SRT at baseline and at 1 year than less severely injured patients. Adolescents obtained lower verbal memory scores than children at 1 year post injury (Levin, High et al., 1988). This finding is in agreement with the results of Levin, Eisenberg, Wigg and Kobayashi, (1982).

Closed Head Injury, Intelligence and Memory

In this section research combining closed head injury, intelligence and memory will be presented. Little research has been done in this area with children. The research that has been done involves a variety of memory tests. Most research in this area is done using head injured adults as subjects. With this population the WMS-R is usually the test of choice to measure memory functioning.

The longitudinal studies referred to earlier showed that at 3 years post injury the moderately and severely injured children showed continued deficits in memory. The studies also found that at 1 month post injury the more severely injured children performed poorer than less severely injured children on the WISC-R (Jaffe et al., 1992). This trend continued at 3 years post injury (Fay et al., 1994). The conclusion that can be reached is that children who had severe closed head injuries continued to have residual intellectual and memory deficits years after their injury.

Donders (1993) concluded that children who had suffered a traumatic brain injury experienced deficits in the recall of both verbal and nonverbal information. It was also found that mild and moderate brain injured children had a significantly higher PIQ than that of severely injured children on the WISC-R. There were no significant group differences on the VIQ scores (Donders, 1993). Levin, Eisenberg, Wigg and Kobayashi (1982) found that children and adolescents with severe closed head injury had a nonsignificant trend for lower PIQ than those with less severe injuries. At a 1 year follow up, 33% of children with severe injuries had a VIQ of less than 80 and 40% of children with severe injuries had a PIQ of less than 80. It was concluded that a subnormal IQ was significantly related to impairment of memory storage in children but was not associated with deficits in retrieval from long term store or impaired recognition memory (Levin et al., 1982). None of the adolescents obtained subnormal IQ scores but at follow up, severely injured adolescents still exhibited impaired memory storage and retrieval (Levin et al., 1982). These articles support the notion that children with severe injuries exhibit both impaired memory and intellectual ability.

Levin, Goldstein, High and Eisenberg (1988) conducted a study of adults who had received moderate or severe closed head injuries. These adults were given the WAIS, the SRT as a measure of verbal memory and the Continuous Recognition Memory Test as a measure of visual memory. It was found that 76% of those with moderate closed head injury and 60% of those with severe closed head injury obtained both VIQ and PIQ scores of 85 or higher. Disproportionate memory impairment was defined by standard scores on both memory tests of below 85 and at least 15 points less than the corresponding VIQ and PIQ scores. This pattern was found in 16% of the moderately injured patients and 25% of the severely injured patients, and in none of the control subjects (Levin, Goldstein et al., 1988). The memory impaired group recalled significantly fewer words after a delay of 30 minutes than the unimpaired group, at both time intervals of 5-15 months and 16-42 months post accident. Severity of injury tended to be greater in patients who had global cognitive impairment that was indicated by low scores on both the memory tests and the IQ test (Levin, Goldstein et al., 1988).

Soloman, [illegible]ne, Farr and Kelly (1986) studied adults who acquired closed head injuries and found that adults obtained average WAIS scores, and scores on the WMS that were lower than the expected mean performances based on other studies. Soloman et al. (1986) found that a closed head injury affected memory scores to a greater extent than IQ scores. Memory Quotient (MQ) and IQ scores were highly correlated (r=0.76) which indicates a high degree of shared variance between the tests in this group of patients (Soloman et al.). There was a mean discrepancy score between the MQ and IQ of 3.14 points, which is smaller than previously found in other research, however, it could be due to a function of sample size. One limitation to this study is that the severity of the injury is not mentioned. The results of the Soloman et al. study supported the results of the Levin, Goldstein et al. (1988) study which found that patients with closed head injuries have lower memory scores than IQ scores.

Bornstein, Chelune and Prifitera (1989) conducted a study that compared memory indexes on the WMS-R with the IQ scores on the WAIS-R in both normal and clinical populations. The clinical population included patients with the diagnoses of epilepsy, dementia, head injury, encephalitis, aneurysm and Korsakoff's syndrome while the normal population included subjects from the WMS-R standardization sample. It was found that 24% of normal subjects and 29% of clinical subjects had a discrepancy of 12 points or more favouring VIQ than on the Verbal Memory Index (Bornstein et al., 1989). One-quarter of normal subjects and one-third of patients had a discrepancy of 12 points or more favouring PIQ than on the Visual Memory Index (Bornstein et al.).

A significant difference was found in the discrepancies between the mean FSIQ and Delayed Memory Index scores in both the clinical and normal populations (Bornstein, Chelune & Prifitera, 1989). The largest discrepancy was found in the Alzheimer's dementia group (Bornstein et al., 1989). This study was limited by the diagnoses of the clinical subjects used, as these illnesses are associated with memory and intellectual problems (Bornstein et al.). It is difficult to determine if the results were due to actual differences between the populations or due to the cognitive effects associated with that diagnosis. This study was also limited by the small sample size, and the normal control sample may have been less than ideal as it contained subgroups from the WMS-R normative sample who had also received the WAIS-R (Bornstein et al.).

Hall and Bornstein (1991) compared mild head injured adults to a normal control population on measures of memory as measured by the WMS-R, and on measures of intelligence, as measured by the WAIS-R. It was found that minor head injuries resulted in greater memory impairment than intellectual impairment on the FSIQ (Hall & Bornstein, 1991). It was also noted that the discrepancy scores were not significant for length of time post injury. An interesting result was that the normal control subjects had higher Delay Memory Index scores than FSIQ scores, but those with closed head injuries obtained the reverse (Hall & Bornstein, 1991). This finding is consistent with previous research on patients with more serious injuries and suggests that a disproportionate effect on memory also occurs with mild injuries. The present study investigates whether children and adolescents (aged 9-18 years) also experience greater memory impairment than intellectual impairment as a result of suffering a closed head injury.

Chapter 3

Methodology

Subjects

The sample consisted of 27 children and adolescents who had experienced a closed head injury and who were assessed at the Glenrose Rehabilitation Hospital. The 27 subjects in the sample consisted of 17 males and 10 females. Subjects selected for the sample had received a moderate or severe traumatic brain injury. The sample included 1 moderate head injured child (GCS score 9-12, PTA of 1-24 hours). All severe head injured children had a GCS score of 0-8 and a loss of consciousness of more than 24 hours. There were 2 severe head injuries (PTA of 1-7 days), 14 very severe head injuries (PTA 1-4 weeks) and 10 extremely severe head injuries (PTA of more than 4 weeks).

All but 1 subject experienced a loss of consciousness with a duration ranging from 1-60 days. The mean was 10.81 days (SD=12.13). The GCS scores ranged from 2-14 with a mean of 6.73 and a standard deviation of 2.96. PTA ranged from 1-140 days with a mean of 33.26 days (SD=33.42). The closed head injuries were received in a motor vehicle accident (n=14), motor vehicle-pedestrian accident (n=6), motor vehicle-bicycle accident (n=2), dirt bike accident (n=2), fall (n=2) and a bicycle accident (n=1).

The subjects ranged in age from 9 years 3 months to 18 years 9 months at the age of assessment. Mean age was 13 years 11 months (SD=2 years 8 months). The assessments were conducted at 0 to 48 months following the accident. The mean was 13.52 months (SD=12.85). Some of the assessments were conducted during the first 6 months after the accident (n=15) and the rest were conducted 1 year or more after the accident (n=12). The sample was split into two age groups in order to compare the performance of younger children to the performance of older children. The younger group included children aged 9-13 years (n=10) and the older group included children aged 14-18 years (n=17).

Normative Sample

The normative database consisted of 716 children recruited from schools in the Edmonton Public School system. These children were part of a study conducted by Miller, Paniak and Murphy (1993). An information letter was sent to parents or guardians explaining the purpose of the study and requesting consent to participate. It also contained questions to help limit the sample to subjects with no biasing conditions. If English was not the main language spoken at home or if the child was enroled in an English as a Second Language class the child was excluded. Children who had experienced a grade failure or attended a special education class were also excluded. Those children who received special help for learning difficulties were excluded from the study if the source of the problem was a documented brain injury or major psychiatric disorder. Exclusion criteria also included those children who had been hospitalized because of brain injury or behaviourial problems or who had required hospital treatment for a diagnosis of Attention Deficit Hyperactivity Disorder. The group consisted of 326 males and 390 females with a mean age of 11.80 years (SD=3.97). These children were estimated to have normal verbal intelligence as they obtained a mean WISC-III Vocabulary Scaled score of 10.34 (SD=2.66). The children were also given other tests including the Wechsler Memory Scale-Revised (WMS-R) subtests.

Testing Instruments

The results of the intelligence tests, the WISC-R, WISC-III and the WAIS-R, and the memory test, the WMS-R were used in this study.

The Wechsler intelligence scales were used to provide a global index of intellectual functioning as well as a measure of verbal and performance abilities. For this study the main focus will be on the FSIQ, VIQ and PIQ scores. Only significant results on the subtests that are common to all Wechsler scales will be reported. The common subtests on the Verbal Scale are: Information, Similarities, Arithmetic, Vocabulary, Comprehension and Digit Span. The common subtests on the Performance Scale are: Picture Completion, Picture Arrangement, Block Design, Object Assembly, Coding and Digit Symbol.

The Verbal, Performance and Full Scale Iqs have a mean of 100 (SD=15). The subtest scaled scores have a mean of 10 (SD=3). The WISC-R's average internal consistency reliability coefficients across all age ranges for Verbal, Performance and Full Scale IQs are 0.94, 0.90 and 0.96 respectively (Wechsler, 1974). The average internal consistency reliability coefficients ranged from 0.77 to 0.86 for the Verbal subtests and from 0.70 to 0.85 for the Performance subtests (Wechsler, 1974). The WISC-R is considered to have a very high test-retest reliability. The average stability coefficient for Verbal, Performance and Full Scale IQs are 0.93, 0.90 and 0.95 respectively (Wechsler, 1974). The average stability coefficients are between 0.77 and 0.88 for the Verbal subtests and are between 0.71 and 0.81 for the Performance subtests (Wechsler, 1974).

The average internal consistency reliability coefficients across all age ranges on the WISC-III Verbal, Performance and Full Scale IQs are 0.95, 0.91 and 0.96 respectively (Wechsler, 1991). The average internal consistency reliability coefficients across all ages ranged from 0.77 to 0.85 for the Verbal subtests and for the Performance subtests ranged from 0.69 to 0.87 (Wechsler, 1991). Average test-retest stability coefficients across all ages for the Verbal, Performance and Full Scale IQs are 0.94, 0.87 and 0.94 respectively (Wechsler, 1991). The average stability coefficients across all ages for the Verbal subtests are 0.73 to 0.89 and for the Performance subtests are 0.64 to 0.81 (Wechsler, 1991). The WISC-III possesses adequate stability coefficients across time and across ages.

The WAIS-R internal consistency for the 16 and 17 year old group for Verbal, Performance and Full Scale IQs are 0.95, 0.88 and 0.96 respectively (Wechsler, 1981). While for the 18 and 19 year old group the internal consistency for the Verbal, Performance and Full Scale IQs are 0.96, 0.90 and 0.96 respectively (Wechsler, 1981). For ages 16 and 17 years the Verbal subtests have an internal consistency of 0.73 to

0.96 while for ages 18 and 19 years it ranges from 0.80 to 0.96 (Wechsler, 1981). On the Performance subtests the internal consistency for ages 16 and 17 years ranges from 0.52 to 0.87 while for ages 18 and 19 years it ranges from 0.70 to 0.87 (Wechsler, 1981). The test-retest stability coefficients for the 25-34 year old group for Verbal, Performance and Full Scale IQs are 0.94, 0.89 and 0.95 respectively (Wechsler, 1981). The stability coefficients for the Verbal subtests range from 0.79 to 0.93 and for the Performance subtests range from 0.69 to 0.91 (Wechsler, 1981).

The correlations between the WISC-III and the WISC-R are reported to be 0.90, 0.81 and 0.89 for Verbal, Performance and Full Scale IQs respectively (Wechsler, 1991). For the Verbal subtests the correlations range from 0.67 to 0.80 and for the Performance subtests the correlations range from 0.42 to 0.76 (Wechsler, 1991). Correlations between the WISC-III and the WAIS-R are reported to be 0.90, 0.80 and 0.86 for the Verbal, Performance and Full Scale IQs respectively (Wechsler, 1991). For Verbal subtests the correlations range from 0.51 to 0.79 and for the Performance subtests the correlations range from 0.35 to 0.79 (Wechsler, 1991).

Correlations between the WISC-R and the WAIS-R for the 16 year old group are reported to be 0.89, 0.76 and 0.88 for Verbal, Performance and Full Scale IQs respectively (Wechsler, 1981). The correlations for the Verbal subtests range from 0.63 to 0.86 and for Performance subtests range from 0.39 to 0.72 (Wechsler, 1981). Similar results were found by Sandoval, Sassenrath and Penaloza (1988) who reported correlations of 0.96, 0.82 and 0.96 for the Verbal, Performance and Full Scale IQs respectively in a sample of learning disabled students. The correlations for the Verbal subtests ranged from 0.47 to 0.93 while the correlations for the Performance subtests ranged from 0.28 to 0.72 (Sandoval et al., 1988). Zimmerman, Covin and Woo-Sam (1986) reported correlations of 0.84, 0.86 and 0.88 for Verbal, Performance and Full Scale IQs in a sample of students with borderline intelligence. These results are similar to those found in the manual and support the idea that the two tests are significantly related.

The WMS-R is used to assess verbal and nonverbal memory. Logical Memory I (LM I) is a test of immediate verbal recall. The examinee listens to two stories and then immediately retells them from memory. Logical Memory II (LM II) is a test of delayed recall that is administered 30 minutes after LM I has been completed. The examinee retells the stories that were previously heard. Visual Reproduction I (VR I) is a test of immediate visual recall. The examinee looks at four geometric designs in order for 10 seconds each and then draws them immediately from memory. Visual Reproduction II (VR II) is a measure of delayed recall. After a delay of 30 minutes the examinee draws the designs from memory. Both Logical Memory and Visual Reproduction have savings scores that utilize both the immediate and delayed recall scores. They are calculated by dividing the delayed recall score by the immediate recall score and multiplying the result by 100.

The WMS-R data in this study will be compared to the normative database that was collected by Miller, Paniak and Murphy (1993). The reliability information presented here was obtained from the WMS-R manual for ages 16 and 17 years. The reliability for these measures is considered to be good. The average internal consistency reliability coefficients for ages 16 and 17 years for LM I, LM II, VR I and VR II are 0.71, 0.71, 0.71 and 0.38 respectively (Wechsler, 1987). The average internal consistency reliability coefficients for all ages for LM I, LM II, VR I and VR II are 0.74, 0.75, 0.59 and 0.46 respectively (Wechsler, 1987). Stability coefficient data are not available for ages 16 and 17 years but are for ages 20-24 years. The WMS-R has good stability when retesting occurs at a 4-6 week interval. The stability coefficients for LM I, LM II, VR I and VR II are 0.67, 0.72, 0.80 and 0.58 respectively (Wechsler, 1987).

Procedure

Permission to conduct this study was obtained from the Department of Educational Psychology Ethics Committee at the University of Alberta. The Glenrose Rehabilitation Hospital Research Ethics Committee granted permission for the use of data from the Glenrose Rehabilitation Hospital. The 27 subjects who had received a closed head injury had a neuropsychological assessment that was conducted at the Glenrose Rehabilitation Hospital. Part of this assessment included the Logical Memory I and II and the Visual Reproduction I and II subtests of the WMS-R and either the WISC-R, WISC-III or the WAIS-R. The 716 subjects from the normative database were volunteers from Edmonton Public Schools (Miller, Paniak & Murphy, 1993). Permission to test these children was obtained from the parents or guardians. Permission was also obtained from the Edmonton Public School Board for the use of their schools. The children were administered the Logical Memory I and II and the

Visual Reproduction I and II subtests of the WMS-R as part of a larger test battery over a one-hour time period.

Hypotheses

This study was conducted to investigate the following statistical hypotheses:

H1: There will be a significant correlation between the FSIQ on the intelligence tests and the scores on the WMS-R variables.

a) Children with less severe head injuries will perform significantly better on the intelligence variable (FSIQ) and the WMS-R variables than children with more severe head injuries.

b) Children who are 1 year or more post injury will perform significantly better on the FSIQ score and the WMS-R variables than children who are 6 months or less post injury.

c) Older children will perform significantly better than younger children on the FSIQ and the WMS-R variables.

d) There will be a significant gender difference on the scores of the FSIQ and the WMS-R variables.

H2: There will be a significant correlation between Verbal intelligence (VIQ) and the scores on the WMS-R variables.

a) Children with less severe head injuries will perform significantly better on the verbal intelligence variable (VIQ) and the WMS-R variables than children with more severe head injuries.

b) Children who are 1 year or more post injury will perform significantly better on a measure of verbal intelligence (VIQ) and the WMS-R variables than children who are 6 months or less post injury.

c) Older children will obtain a significantly higher score on VIQ and the WMS-R variables than younger children.

d) There will be a significant gender difference on the scores of the VIQ and the WMS-R variables.

H3: There will be a significant correlation between nonverbal intelligence (PIQ) and the scores on the WMS-R variables.

a) Children with less severe head injuries will perform significantly better on a measure of nonverbal intelligence (PIQ) and the WMS-R variables than children with more severe head injuries.

b) Children who are 1 year or more post injury will perform significantly better on a measure of nonverbal intelligence (PIQ) and the WMS-R variables than children who are 6 months or less post injury.

c) Older children will obtain a significantly higher score on PIQ and the WMS-R variables than younger children.

d) There will be a significant gender difference on the scores of the PIQ and the WMS-R variables.

H4: A significant difference between memory scores on the WMS-R and the severity of injury will be found as well as a significant difference between intelligenc test scores and severity of injury.

H5: A significant difference between memory scores on the WMS-R and time since injury will be found as well as a significant difference between intelligence test scores and time since injury.

H6: A significant difference between memory scores on the WMS-R and the age of the child will be found as well as a significant difference between intelligence test scores and the age of the child.

H7: A significant difference between memory scores on the WMS-R and the gender of the child will be found as well as a significant difference between intelligence test scores and the gender of the child.

A further goal of the research will be to compare these scores on the intelligence measures to the norms provided in the manuals and the scores on the WMS-R variables to the normative database. Due to the small sample size a statistical comparison cannot be done.

Data Analysis

Means and standard deviations were calculated for the WMS-R variables and the intelligence scales. Correlations between the WMS-R variables and the intelligence scales variables were calculated. MANOVA's were calculated to determine whether the dependent variables (WMS-R variables) differed depending on the severity of the injury, time since accident, age of the child and the gender of the child. T-tests of two independent means were conducted to determine if the IQ scores differed depending on the severity of injury, time since accident, age of the child and gender of the child. Means and standard deviations were calculated by age for the WMS-R variables and the intelligence variables. These scores will be compared to the results of the WMS-R variables in the normative database and to the normative data in the Wechsler Intelligence Scales manuals.

Chapter 4

Results

The findings of the data analysis are presented in this chapter. The purpose of the analyses was to determine the relationship between intellectual ability and the WMS-R variables in a pediatric closed head injured population.

H1: There will be a significant correlation between the FSIQ on the intelligence tests and the scores on the WMS-R variables.

To test this hypothesis, correlations were performed between the FSIQ score and the WMS-R variables. Significant correlations ($p<.05$) were found between FSIQ and Logical Memory I, II and Visual Reproduction II ($r=.4246$, $r=.3814$ and $r=.4053$, respectively). A significant correlation ($p<.0001$) was found between FSIQ and Visual Reproduction I ($r=.6519$). See Table 1 for the correlations.

To test each of the subsections (severity, time since accident, age and gender) of this hypothesis correlations were also performed. Both levels of severity produced significant correlations ($p<.05$) with Visual Reproduction I. A very severe injury produced a correlation of $r=.6508$ and an extremely severe injury produced a correlation of $r=.7193$ (see Table 2). FSIQ correlated with Visual Reproduction II ($r=.5392$, $p<.05$) for those children were less than

Table 1

Correlations between IQ scores and WMS-R variables (n=27)

	FSIQ	VIQ	PIQ
LM I	.4246*	.4532*	.3247
LM II	.3814*	.3762	.3248
LMSS	.0477	.0420	.0473
VR I	.6519**	.5600*	.6263**
VR II	.4053*	.3590	.4030
VRSS	.3104	.2807	.3110

LM I = Logical Memory I
LM II = Logical Memory II
LMSS = Logical Memory Savings Score
VR I = Visual Reproduction I
VR II = Visual Reproduction II
VRSS = Visual Reproduction Savings Score
FSIQ = Full Scale Intelligence Quotient
VIQ = Verbal Intelligence Quotient
PIQ = Performance Intelligence Quotient

two-tail significance
* $p < .05$
** $p < .0001$

Table 2

Correlations between IQ scores and WMS-R variables by Severity of Injury

	FSIQ		VIQ		PIQ	
	V. Sev.	E. Sev.	V. Sev.	E. Sev.	V. Sev.	E. Sev.
LM I	.1939	.6611	.3094	.5928	.0566	.6370*
LM II	.1201	.5700	.1683	.5064	.3094	.5656
LMSS	-.1947	.0604	-.3511	.0951	-.0677	.0235
VR I	.6508*	.7193*	.5815*	.6776*	.6102*	.6407*
VR II	.1940	.5152	.0324	.5567	.3052	.4178
VRSS	.0237	.3943	-.1482	.4192	.1742	.3338

Two-tail significance * $p < .05$

V. Sev. = Very Severe (n=14)
E. Sev. = Extremely Severe (n=10)

6 months post injury. Significant correlations ($p<.05$) were found with Logical Memory I and II ($r=.6188$ & $r=.6049$, respectively) for those children who were more than 1 year post injury.

Significant correlations were obtained for children aged 14-18 years at the $p<.05$ level for Logical Memory I, II and Visual Reproduction II ($r=.5308$, $r=.5025$ & $r=.5180$, respectively) and a correlation at $p<.0001$ level was obtained for Visual Reproduction I ($r=.8540$). There were no significant correlations for the 9-13 year old group (see Table 4). No significant correlations were found for males but several significant correlations were found for females. These are depicted in Table 5. At the $p<.05$ level significant correlations were found for Logical Memory II and savings score, and Visual Reproduction II ($r=.6541$, $r=.6715$ & $r=.5570$, respectively) while at the $p<.0001$ level a significant relationship was found with Visual Reproduction I ($r=.9211$). The correlation between FSIQ and Logical Memory I approached significance ($r=.6133$, $p=.059$).

Overall these findings support the hypothesis that there will be a significant correlation between FSIQ and the WMS-R variables. With the exception of the savings scores FSIQ correlated significantly with both Logical Memory and Visual Reproduction subtests. Children who experienced extremely severe injuries obtained higher correlations than less severely injured children. Those children who

Table 3

Correlations between IQ scores and WMS-R variables by Time Since Accident

	FSIQ		VIQ		PIQ	
	< 6 mos.	> 1 yr	< 6 mos.	> 1 yr	< 6 mos.	>1 yr
LM I	.0084	.6188*	.1193	.5880*	-.0676	.5503
LM II	-.0254	.6049*	.0580	.5343	-.0688	.5807*
LMSS	.0235	.0571	.0594	.0446	.0071	.0553
VR I	.4531	.8191**	.4041	.6755*	.4172	.8430**
VR II	.5392*	.3229	.4518	.2894	.5396*	.3367
VRSS	.4538	.2350	.3604	.2191	.4802	.2443

Two-tail significance * $p < .05$ ** $p < .001$

< 6 mos. = Less than 6 months since accident (n=15)
> 1 yr = More than 1 year since accident (n=12)

Table 4

Correlations between IQ scores and WMS-R variables by Age of the Child

	FSIQ		VIQ		PIQ	
	9-13 yr	14-18 yr	9-13 yr	14-18 yr	9-13 yr	14-18 yr
LM I	.3286	.5308*	.2673	.5622*	.3191	.4109
LM II	.2973	.5025*	.1617	.5076*	.3624	.4144
LMSS	.1019	.0802	-.0317	.0863	.2127	.0584
VR I	.4189	.8540**	.1299	.7747**	.5383	.7935**
VR II	.1703	.5180*	-.2137	.5165*	.4035	.4630
VRSS	-.0248	.4140	-.3289	.4272	.1936	-.3623

Two-tail significance * $\underline{p} < .05$ ** $\underline{p} < .0001$

9-13 years (n=10)
14-18 years (n=17)

experienced their head injury 1 or more years earlier performed significantly better than those injured more recently for all the Logical Memory variables and Visual Reproduction I variable. Older children generally obtained higher correlations than younger children for both the Logical Memory variables and the Visual Reproduction variables with the exception of the Visual Reproduction savings scores. Females obtained higher correlations than males on all WMS-R variables. All variables reached significant levels, except for Logical Memory I which was approaching significance and the Visual Reproduction savings score which was not significant.

H2: There will be a significant correlation between verbal intelligence (VIQ) and the scores on the WMS-R variables.

Correlations were performed between VIQ and the WMS-R variables. Both Logical Memory I and Visual Reproduction I correlated significantly with VIQ ($r=.4532$ & $r=.5600$, $p<.05$, respectively). Logical Memory II and Visual Reproduction II both had correlations that approached significance as depicted in Table 1 ($p=.053$ & $p=.066$, respectively). Table A1 in Appendix A depicts that Logical Memory I correlated at the $p<.05$ level with Similarities, Vocabulary and Comprehension while Logical Memory II correlated at the $p<.05$ level with Comprehension and approached significance

Table 5

Correlations between IQ scores and WMS-R variables by Gender

	FSIQ		VIQ		PIQ	
	Male	Female	Male	Female	Male	Female
LM I	.3774	.6133	.4011	.6889*	.2194	.5272
LM II	.2056	.6541*	.2048	.7203*	.1284	.5822
LMSS	-.3382	.6715*	-.2952	.7399*	-.2734	.6066
VR I	.3029	.9211***	.2140	.9122***	.3126	.8803**
VR II	.3265	.5570*	.2766	.5272	.3132	.5587
VRSS	.2523	.4311	.2149	.4258	.2486	.4253

Two-tail significance * $p < .05$ ** $p < .001$ *** $p < .0001$

Male (n=17)
Female (n=10)

for Vocabulary (p=.062). Information and Vocabulary correlated with Visual Reproduction I at the p<.05 level and the Similarities approached significance (p=.065) with Visual Reproduction I.

Significant correlations were obtained for both levels of severity of injury with Visual Reproduction I at the p<.05 level (very severe r=.5815 & extremely severe r=.6776). These results are shown in Table 2. For the very severely injured children the verbal subtests that correlated with Visual Reproduction I at the p<.05 level were Information, Similarities, Vocabulary and Digit Span. For children with extremely severe injuries, Similarities and Vocabulary correlated with Logical Memory I, Comprehension with Logical Memory II, and Information and Vocabulary with Visual Reproduction I at the p<.05 level. See Tables A2 and A3 in Appendix A.

No significant correlations were found between VIQ and the WMS-R variables for children who had experienced their head injury within the last 6 months. For those children who were 1 year or more post head injury, both Logical Memory I and Visual Reproduction I correlated significantly with VIQ at the p<.05 level (r=.5580 & r=.6755, respectively). More than 1 year after the accident only the Vocabulary correlated with Visual Reproduction I (r=.6618, p<.05). These results are indicated in Table 3 and Table A5 in Appendix A respectively.

Significant correlations were not found for children aged 9-13 years between VIQ and the WMS-R variables. Significant correlations were found between VIQ and Logical Memory I, II and Visual Reproduction II at the p<.05 level (r=.5622, r=.5076 & r=.5165, respectively) for children aged 14-18 years. Visual Reproduction I and

VIQ obtained a correlation of r=.7747, p<.0001. The older children obtained significant correlations for Logical Memory I and II with Vocabulary and Comprehension, while Logical Memory II also obtained a significant correlation with Similarities at the p<.05 level. Visual Reproduction I correlated with all verbal subtests except Arithmetic, while Visual Reproduction II approached significance for Vocabulary (p=.054) and Digit Span (p=.067) for children aged 14-18 years. The results for the subtests are presented in Appendix A, Table A6 and A7.

Only females obtained significant results for all Logical Memory variables (p<.05) and for Visual Reproduction I (p<.0001). The results are presented in Table 5. Several verbal subtests correlated with the WMS-R variables for females. Comprehension correlated with Logical Memory I, II and savings score (r=.8577, p<.05, r=.8629, p<.001 & r=.7144, p<.05, respectively). The correlation for Information approached significance for both Logical Memory I and II (p=.061 & p=.054). The Logical Memory savings score correlated with Similarities and Vocabulary approaching significance (p=.057 & p=.063, respectively). Correlations for Visual Reproduction I reached significance for Information, Similarities, Digit Span (p<.05) and Vocabulary (p<.0001), and approached significance for Comprehension (p=.060). Only Similarities reached significance for Visual Reproduction II (p<.05). These results are presented in Appendix A, Table A8 and A9.

The findings of the hypothesis generally support the idea that there is a relationship between VIQ and the WMS-R variables, particularly the Logical Memory variables. Children with an extremely severe injury obtained higher correlations between VIQ and all WMS-R variables but only Visual Reproduction I reached significance. Children who are 1 or more years post injury obtained significant correlations with VIQ and Logical Memory I and Visual Reproduction I. Older children also performed significantly better on all WMS-R variables than younger children. Females obtained higher correlations than males on all WMS-R variables and most of these reached significance.

H3: There will be a significant correlation between nonverbal intelligence (PIQ) and the scores on the WMS-R variables.

Correlations were performed between PIQ and the WMS-R variables to determine the relationship between these two

variables. PIQ had low correlations with all WMS-R variables with the exception of Visual Reproduction I which was significant at the $p<.0001$ level ($r=.6263$). These correlations can be found in Table 1. Picture Arrangement correlated significantly with both Logical Memory I and II and Object Assembly correlated significantly with Logical Memory II at the $p<.05$ level. Visual Reproduction I correlated with both Picture Completion and Picture Arrangement of the $p<.05$ level; with Block Design at the $p<.001$ level and Object Assembly at the $p<.0001$ level. The Visual Reproduction savings score approached significance when correlated with Object Assembly ($p=.056$). The results for the performance subtests can be found in Appendix A, Table A1.

On all WMS-R variables children with an extremely severe injury obtained higher correlations than those with a less severe injury. Only the correlations for Logical Memory I and Visual Reproduction I were significant at the $p<.05$ level ($r=.6370$ & $r=.6407$, respectively). These results are depicted in Table 2. When focusing on children with very severe injuries only Object Assembly on the Performance Scale reached significance and Block Design approached significance ($p=.069$) for Visual Reproduction I. Object Assembly also approached significance for Visual Reproduction II ($p=.074$). Children with extremely severe injuries obtained significant correlations for both Block Design and Object Assembly on Visual Reproduction I at the $p<.05$ level. These results are presented in Appendix A, Tables A2 and A3.

Children who were less than 6 months post injury obtained lower correlations on the Logical Memory I, II, savings score and Visual Reproduction I than those who were more than 1 year post injury. At 1 year or more since the accident Logical Memory II was significant at the $p<.05$ level and Logical Memory I approached significance ($p=.064$). The correlations were $r=.5807$ and $r=.5503$ respectively. Table 3 indicates that with the exception of Visual Reproduction I ($r=.8430$, $p<.001$) the visual memory correlations are lower at 1 year post injury than those obtained by children who were injured more recently. Significant correlations were obtained between Picture Arrangement and Logical Memory I and II, between Object Assembly and Logical Memory II and between Block Design and Visual Reproduction I at the $p<.05$ level. Object Assembly and Visual Reproduction I were significantly correlated at the $p<.0001$ level. Visual Reproduction I and Picture Arrangement and

Coding/Digit Symbol approached significance (p=.055 & p=.067, respectively). These correlations are depicted in Appendix A, Table A5.

No significant relationship was found between PIQ and the WMS-R variables for children aged 9-13 years (Table 4). Children aged 14-18 years obtained higher correlations than younger children for all WMS-R variables except for both savings scores. For the older children only Visual Reproduction I was significant (r=.7935, p<.0001). Picture Arrangement correlated with Logical Memory II and Visual Reproduction I, and Object Assembly correlated with Logical Memory I, Visual Reproduction II and the savings score at the p<.05 level for older children. Object Assembly approached significance when correlated with Logical Memory II (p=.074) and correlated with Visual Reproduction I at the p<.0001 level. The older children's score on Coding/Digit Symbol and Picture Completion correlated with Visual Reproduction I at the p<.05 level and Block Design correlated with Visual Reproduction I at the p<.0001 level (see Table A7, Appendix A).

There were no significant correlations found for males between the WMS-R variables and PIQ (Table 5) but Object Assembly did correlate with Visual Reproduction I at the p<.05 level (Table A9, Appendix A). Females obtained a significant correlation for PIQ and Visual Reproduction I (r=.8803, p<.001) and the correlation for Logical Memory savings score approached significance (p=.063). These results are found in Table 5. Significance at the p<.05 level was obtained for correlations between Visual Reproduction I and Picture Completion, Picture Arrangement, Block Design and Coding/Digit Symbol. Object Assembly correlated significantly with Visual Reproduction I ($p<.0001$), and Visual Reproduction II ($p<.05$) and approached significance with Logical Memory II ($p=.068$). Significance was approached for correlations of Picture Arrangement and Logical Memory II and the savings scores ($p=.065$ & $p=.061$, respectively). The subtest correlations can be found in Table A8 in Appendix A.

Overall there is little support for the hypothesis that there will be a significant relationship between PIQ and the WMS-R variables. Children with an extremely severe head injury obtain higher correlations than less severely injured children between PIQ and the WMS-R variables. Only Logical Memory I and Visual Reproduction I reached significance. Children who were 1 year or more post injury obtained higher correlations and more significant correlations than those children who were more recently injured. The exception to this was Visual Reproduction II and the savings score in which higher correlations were obtained for children who were less than 6 months post injury. Children aged 14-18 years obtained higher correlations on all WMS-R variables except the savings scores. Only the correlation with Visual Reproduction I reached significance. Females also obtained higher correlations than males on all WMS-R variables but only Visual Reproduction I reached significance and the Logical Memory savings score approached significance.

H4: A significant difference between memory scores on the WMS-R and severity of injury will be found as well as a significant difference between intelligence test scores and severity of injury.

To determine if there is a significant difference between memory scores on the WMS-R and severity of injury a MANOVA was performed. Using Hotellings criterion a significant main effect $F(3,20)=.64622$ ($p<.05$) was found for Logical Memory and severity of injury (Table 6). Children who had a very severe injury scored higher on Logical Memory variables than children who had an extremely severe injury. A MANOVA for Visual Reproduction did not produce a significant main effect for severity of injury. This indicates that the effect of severity of injury does not produce a difference in performance on Visual Reproduction. The hypothesis received partial support as only Logical Memory produced a significant main effect.

T-tests were conducted to determine if there is a significant difference between intelligence test scores and severity of injury. Tables 8, 9 and 10 report the results of the T-tests for VIQ, PIQ and FSIQ. No significant differences were found based on severity of injury. This indicates that there was no significant difference in performance on the intelligence scales for children with a very severe head injury and those with an extremely severe head injury. A significant difference was found for the subtest Coding/Digit Symbol at the $p<.05$ level (Table B11, Appendix B). This result indicates that those children with a less severe injury are able to obtain higher scores on this subtest than children with a more severe injury. This part of the hypothesis was not supported by the data.

H5: A significant difference between memory scores on the WMS-R and time since injury will be found as well as a significant difference between intelligence test scores and time since injury.

A MANOVA was performed to determine if there is a significant difference between memory scores on the WMS-R and time since injury. Hotellings criterion was used but no significant main effect was found for either Logical Memory or Visual Reproduction (Tables 6 and 7). This indicates that time since injury did not affect the performance on either of the memory tasks. This hypothesis was not supported by the data.

T-tests were conducted to determine if there was a significant difference between intelligence test scores and time since injury. No significant difference was found for time since injury for VIQ, PIQ or FSIQ. This indicates that time does not affect performance on the intelligence test. This hypothesis was also not supported by the data.

Table 6

Multivarate Analysis of Variance for Logical Memory Variables

	Hotellings	Exact F Hypot.	DF	p
Severity	.64622	4.30815	3/20	.017*
Time Since Accident	.01081	.08290	3/20	.969
Age	.10357	.79403	3/20	.510
Gender	.12444	.95405	3/20	.431

Two-tail significance   *$p < .05$

Table 7

Multivarate Analysis of Variance for Visual Reproduction Variables

	Hotellings	Exact F Hypot	DF	p
Severity	.11024	.73493	3/20	.543
Time Since Accident	.07130	.54662	3/20	.655
Age	.30744	2.35704	3/20	.098
Gender	.02774	.21269	3/20	.887

Table 8
T-Test for VIQ

		Mean	SD	df	T	p
Severity	Very Severe	90.0000	9.799	22	1.28	.215
	Extremely Severe	83.1000	16.670			
Time since Accident	< 6 months	88.9333	10.396	25	.42	.676
	> 1 year	86.7500	16.288			
Age	9-13 years	91.0000	7.486	25	.92	.366
	14-18 years	86.1765	15.440			
Gender	Male	90.2943	12.262	25	1.22	.235
	Female	94.000	14.174			

Table 9

<u>T-Test for PIQ</u>

		Mean	SD	df	T	p
Severity	Very Severe	94.5000	15.993	22	.99	.331
	Extremely Severe	87.1000	20.588			
Time since Accident	< 6 months	99.6667	15.272	25	-.64	.530
	> 1 year	93.9167	19.430			
Age	9-13 years	95.500	13.778	25	.92	.366
	14-18 years	89.2353	18.680			
Gender	Male	93.2941	14.564	25	.68	.500
	Female	88.6000	21.099			

Table 10

T-Test for FSIQ

		Mean	SD	df	T	p
Severity	Very Severe	91.0714	12.313	22	1.17	.254
	Extremely Severe	83.7000	18.619			
Time since Accident	< 6 months	88.2667	12.366	25	-.11	.912
	> 1 year	88.9167	17.820			
Age	9-13 years	92.2000	9.998	25	.99	.334
	14-18 years	86.4118	16.819			
Gender	Male	90.9412	12.106	25	1.10	.281
	Female	84.5000	18.350			

H6: A significant difference between memory scores on the WMS-R and the age of the child will be found as well as a significant difference between intelligence test scores and the age of the child.

A MANOVA was performed to determine if there was a significant difference between memory scores on the WMS-R and the age of the child. The children were split into two categories: younger children (9-13 years) and older children (14-18 years). No significant main effect was found for either Logical Memory or Visual Reproduction using Hotellings criterion (Tables 8, 9 & 10). This indicates that the results on the memory variables are not affected by the age of the child. The results of this analysis did not support the hypothesis.

To determine if there is a significant difference between intelligence test scores and age of the child a T-test was conducted. No significant differences were found (Tables 8, 9 & 10). The only subtest to reach significance ($p<.05$) was Coding/Digit Symbol and Similarities approached significance ($p=.058$) as shown in Appendix B, Tables B11 and B2, respectively. These results indicate that the age of the child does not affect the performance on an intelligence test. The hypothesis was not supported by the data.

H7: A significant difference between memory scores on the WMS-R and the gender of the child will be found as well as a significant difference between intelligence test scores and the gender of the child.

To determine if there is a significant difference between memory scores a MANOVA was performed. No significant main effect was found using Hotellings criterion for either Logical Memory or Visual Reproduction (Table 8, 9 & 10). This indicates that gender did not affect the test performance. This hypothesis was not supported.

T-tests were performed to determine if there is a significant difference between intelligence test scores and gender. Table 8, 9 and 10 indicate that no significant differences were found for VIQ, PIQ or FSIQ. Significant differences were found on the Arithmetic subtest ($p<.05$) and approached significance on the Block Design subtest ($p=.052$) as reported in Appendix B, Table B3 and B9 respectively. The data did not support the hypothesis that there will be a significant difference on intelligence test scores due to gender of the child.

Comparison of Clinical to Normative Samples

A comparison was done between the mean IQ scores obtained for the head injured sample and the normative information provided in the manual. A statistical comparison could not be done because at each level there are too few subjects. The means for the intelligence tests are 100 and the standard deviations are 15 (Wechsler, 1974, 1981 and 1991). The mean IQs obtained from this head injured sample, shown in Table 11, were generally lower than the means reported in the manuals. Almost all of the IQs fell within the average range. The exception are the children aged 15 and 16 years. These children obtained IQ scores that placed them below the average range. Although the mean scores were lower for 15 year old subjects, the standard deviations were very large, ranging from 20.53 points for VIQ to 23.51 points for FSIQ. This indicates that some of these children did obtain scores in the average range while others obtained scores that are much lower than the average range. The children in the 16 year old group had a smaller standard deviation, ranging from .71 for FSIQ to 4.24 for VIQ. The results for the 15 and 16 year old subjects could be due to the severity of injury and time since the accident. These children may have experienced more severe injuries or may have been assessed closer to the time of accident than other children.

In general the PIQ scores were greater than the VIQ scores. The exception was for those aged 9, 15 and 16 years. The 15 year old group had a 1.5 point difference between VIQ and PIQ favouring VIQ. The 9 year old group had a difference of 7.66 points and the 16 year old group had a 10 point difference both in favour of VIQ. The difference between VIQ and PIQ favouring PIQ ranged from 3.5 points (11 year old subjects) to 19 points (12 year old subjects).

A comparison was also done comparing the means obtained on the WMS-R variables in the head injured sample to the means obtained in the school aged normative database collected by Miller, Paniak and Murphy (1993). Overall the means for the head injured sample were lower (Table 12) than those in the database (Table 13). Similar means were found for Visual Reproduction I for 10 and 11 year old subjects and for Logical Memory savings score for 14 year old subjects. The 16 to 18 year old subjects were also compared to the normative database. The 18 year old subjects in this sample obtained memory scores that were similar to the scores of the 15 year old subjects in the normative database for all variables. All scores fell within a range of 3 points below (Visual Reproduction II) and 2 points above (Logical Memory savings score) the normative database.

The standard deviations obtained by this clinical sample varies greatly from what was obtained by the normative database. The greatest variability in standard deviations occurred in both the savings scores. The Logical Memory savings score standard deviations vary from .85 (13 year old subjects) to 73.66 (14 year old subjects). The Visual Reproduction savings score standard deviations vary from 2.97 (10 year old subjects) to 43.83 (15 year old subjects). The subjects were able to recall less information after a 30 minute delay than were able to recall immediately after presentation of the stimulus. This indicates that the clinical sample has varying degrees of memory impairment.

Table 11

Means and Standard Deviations for the Wechsler Intelligence Scale Variables

Age		FSIQ	VIQ	PIQ
9	Mean	85.33	90.33	82.67
(n=3)	SD	11.59	10.60	11.37
10	Mean	90.50	87.50	96.50
(n=2)	SD	13.44	9.19	16.26
11	Mean	100.00	98.50	102.00
(n=2)	SD	5.66	2.12	9.90
12	Mean	96.50	88.00	107.00
(n=2)	SD	10.61	5.66	15.56
13	Mean	88.00	86.00	93.50
(n=2)	SD	5.66	7.07	3.54
14	Mean	91.00	89.00	94.83
(n=6)	SD	16.88	17.04	18.24
15	Mean	77.00	79.50	78.00
(n=4)	SD	23.51	20.53	22.98
16	Mean	72.50	79.00	69.00
(n=2)	SD	.71	4.24	1.41
17	Mean	101.00	97.50	106.50
(n=2)	SD	5.66	16.25	9.19
18	Mean	92.00	89.50	97.00
(n=2)	SD	7.07	13.44	4.24

Table 12

Means and Standard Deviations for the WMS-R Variables

Age		LM I	LM II	LMSS	VR I	VR II	VRSS
9	Mean	11.67	8.00	65.25	23.67	14.33	61.49
(n=3)	SD	6.81	5.57	23.91	2.08	3.06	17.93
10	Mean	13.50	10.00	74.70	29.50	22.00	74.50
(n=2)	SD	.11	2.83	24.89	.71	1.41	2.97
11	Mean	16.00	11.50	67.58	30.50	13.00	36.00
(n=2)	SD	4.24	7.78	30.30	7.78	18.38	50.91
12	Mean	15.00	10.00	62.18	29.50	25.00	85.48
(n=2)	SD	5.66	7.07	23.65	2.12	4.24	20.53
13	Mean	15.50	12.50	80.60	35.50	26.50	74.30
(n=2)	SD	.71	.71	.85	.71	12.02	32.39
14	Mean	16.17	12.67	91.75	33.50	16.33	49.70
(n=6)	SD	9.58	9.11	73.66	2.43	11.57	37.39
15	Mean	17.75	12.25	57.43	30.75	22.50	61.68
(n=4)	SD	8.26	8.42	40.48	12.50	16.30	43.83
16	Mean	21.00	19.00	46.39	26.00	12.00	45.07
(n=2)	SD	9.90	4.24	25.19	2.83	5.66	17.07
17	Mean	12.50	10.00	79.80	38.00	34.00	88.50
(n=2)	SD	.71	1.41	6.79	2.83	2.83	12.02
18	Mean	27.50	24.00	90.25	33.00	30.50	93.05
(n=2)	SD	12.02	7.07	13.79	4.24	.71	9.83

Table 13

Means and Standard Deviations of the WMS-R Variables from the Normative Database

Variable		Age 9	10	11	12	13	14	15	Overall Sample
Subjects	N	81	140	132	123	96	116	28	716
Males	n	36	64	76	50	40	45	15	326
Females	n	45	76	56	73	56	71	13	390
LM I	Mean	19.74	21.24	23.23	24.90	25.35	27.78	28.82	24.01
	SD	7.67	7.33	7.39	6.81	6.86	6.44	6.90	7.54
LM II	Mean	17.31	1[illegible].65	20.17	22.31	22.15	24.67	25.57	21.15
	SD	7.61	7.33	6.94	6.81	6.94	6.77	7.46	7.49
LMSS	Mean	88.05	86.61	86.39	89.47	86.68	88.33	87.68	87.55
	SD	21.19	14.50	13.29	11.64	12.54	11.32	12.90	13.98
VR I	Mean	29.25	29.78	31.20	33.32	34.42	35.50	35.43	32.37
	SD	4.33	4.28	4.73	3.65	3.29	2.64	2.43	4.46
VR II	Mean	23.85	26.32	27.08	30.69	31.42	33.66	33.43	29.09
	SD	6.06	5.47	5.75	4.47	5.13	3.76	4.01	6.04
VRSS	Mean	81.51	88.77	86.97	92.36	91.07	94.77	94.11	89.73
	SD	18.02	16.78	14.96	11.06	11.88	9.07	8.94	14.26

Chapter 5

Discussion

This chapter consists of a discussion of the results found in this study and a comparison of these results to the findings of previous research. The results concerning the hypotheses about the relationship between intellectual ability and memory functioning are discussed first; an examination of the results concerning the hypotheses about memory and intelligence follows. The chapter also includes a section of implications for education and suggestions for further research.

Intellectual Ability and Memory Impairment

This section focuses on Hypotheses 1 to 3. These hypotheses address how the relationship between intelligence and memory are affected by severity of injury, time since accident, age and gender of the child.

The results of this study indicate that there is a relationship between intellectual ability and memory impairment. This is particularly true for FSIQ and VIQ and less so for PIQ. FSIQ and VIQ correlated with the Logical Memory I and II variables. Logical Memory I reached significance for both FSIQ and VIQ, while Logical Memory II was significant for FSIQ and approached significance for VIQ. VIQ may have correlated with Logical Memory because both test verbal abilities. PIQ may not have correlated with Logical Memory because it is a measure of nonverbal abilities.

The FSIQ's correlation with Logical Memory may have occurred because of the influence of the VIQ correlation. The FSIQ is comprised of both verbal and nonverbal abilities. There is no relationship between the Logical Memory savings score and any of the IQ scores.

Visual Reproduction I correlated significantly with FSIQ, VIQ and PIQ. Visual Reproduction II correlated significantly with FSIQ and approached significance with VIQ. The size of the correlations for Visual Reproduction were small, between .28 and .65. The visual stimulus may not have been processed as deeply in the head injured sample resulting in weaker correlations. The FSIQ may have correlated with Visual Reproduction variables because of the influence of the PIQ correlations. Visual Reproduction I and II may have correlated with FSIQ and VIQ because there is a verbal component to this task. The shapes may have been remembered because they are named. Research has shown that items that are encoded verbally can be more easily recalled.

There has been little research conducted into the relationship between IQ and memory for adults and even less so for children. The research conducted on children involves the use of memory tests other than the WMS-R. Therefore, it is difficult to determine if the results found in this study are supported by previous research.

It was hypothesized that children with less severe injuries would perform significantly better than those with more severe injuries. The results of the present study found that children with extremely severe injuries obtained higher correlations with the memory variables than children with less severe injuries for all IQ scores.

The hypothesis was not supported. The finding might have occurred because the more of the extremely severe head injured children might have had their assessments at 1 or more years post accident and, therefore, had more time to recover brain functioning.

Reid and Kelly (1993) found that only visual memory correlated significantly with severity of injury, a finding which supports the results of the present study. In addition Reid and Kelly (1993) also found that those with head injuries performed poorly on the Logical Memory and Visual Reproduction savings scores. This result was also found in the present study for the savings score correlations are smaller than the other correlations. Levin, Goldstein, High and Eisenberg (1988) found that some adults who had experienced a moderate or severe head injury were experiencing memory impairment despite recovery to relatively normal intellectual functioning (Levin, Goldstein, et al., 1988). Levin, Eisenberg, Wigg and Kobayashi (1982) concluded that for some children who had experienced severe head injuries, subnormal IQ scores were significantly related to impaired memory storage but not related to deficits in retrieval from long-term store or impaired recognition memory.

Jaffe et al. (1993) found a significant correlation between IQ scores and severity of injury at 1 year post injury, indicating that the more severely injured obtained lower IQ scores. This result was also found at 3 years post injury (Fay, et al., 1994).

It was hypothesized that children who were 1 year or more post injury would perform significantly better than those children who were 6 months or less post injury. It was found that time since accident did result in some significant correlations. Logical Memory I correlated significantly with FSIQ and VIQ, while Logical Memory

II was significantly correlated with FSIQ and PIQ for those who were more than 1 year post accident. Visual Reproduction I correlated significantly with all the IQ scores at 1 year or more post accident. Visual Reproduction II correlated significantly with FSIQ and PIQ at less than 6 months post accident.

Hall and Bornstein (1991) found that FSIQ and Delayed Memory Index were correlated with time since accident but the correlation did not reach significance for a group of adult closed head injured patients. It is difficult to determine if the Hall and Bornstein (1991) findings support what was found in the present study because of the large difference in numbers of subjects who were in the three time categories. The present study had roughly an even number in each time category.

It was hypothesized that older children would perform significantly better than younger children on the IQ and WMS-R variables. The results of the present study found that Logical Memory I and II significantly correlated with both FSIQ and VIQ for older children. Visual Reproduction I significantly correlated with all IQ scores and Visual Reproduction II significantly correlated with FSIQ and VIQ for those aged 14-18 years. The finding may have occurred because the older children had better developed memory skills before the accident and therefore were able to process the information to a deeper level.

[illegible] Levin, Eisenberg, Wigg and Kobayashi (1982) reported age differences in their study. Children, but not adolescents, who had severe closed head injuries experienced residual deficits in recognition memory. Impairment of long-term verbal memory and memory retrieval continued for both children and adolescents with severe head injury. Global intellectual deficit occurs with impaired memory storage in children under the age of 13 years (Levin et al., 1982).

It was hypothesized that there would be a significant gender difference on the IQ and the WMS-R variables. Results indicated that there were several significant correlations for females between the IQ scores and the WMS-R variables. When looking at FSIQ, females obtained significant correlations with Logical Memory II, savings scores and Visual Reproduction I and II. For VIQ, significant correlations occurred between Logical Memory I, II, and savings scores and Visual Reproduction I, but for PIQ the only significant correlation occurred with Visual Reproduction I. Females appear to be better able to process verbal information at a deeper level than figural information. It may be that females are more verbally oriented and, therefore, can more easily recall verbally presented information. In the literature, gender differences were either not reported or significant differences were not found.

Memory

This section focuses on Hypotheses 4 to 7. These hypotheses question whether there are significant differences between memory and the variables of severity of injury, time since injury, age, and gender of the child.

In this study significant main effects were found when comparing the WMS-R variables and severity using a MANOVA for Logical Memory but not Visual Reproduction. Studies of adults have been found to show significant differences in memory functioning due to severity of injury. Levin, Goldstein, High and Eisenberg

(1988) found a significant difference in retrieval of words from verbal memory. More severely injured patients retrieved fewer words than moderately injured.

Reid and Kelly (1993) found statistically significant differences between scores for normal control subjects and for the head injured population, on both Logical Memory and Visual Reproduction. Significant differences were also obtained between the head injured and normal control populations in the amount of information retained, as measured by the Logical Memory and Visual Reproduction savings scores. The control group retained mean percentages greater than the head injured group on Logical Memory and Visual Reproduction (Reid & Kelly, 1993). In the present study children with closed head injury also obtained savings scores that were lower than those of the normative database. This could be suggestive of a lack of deeper processing by head injured children.

Levin, Eisenberg, Wigg and Kobayashi (1982) found that severely injured children entered fewer words into long-term storage than less severely injured children, and were less efficient at retrieving the words from long-term storage. Severity of injury also resulted in significant differences in scores on a task of visual continuous recognition memory. Jaffe et al. (1992) found that more severely injured children remembered significantly fewer words under short-term or long-term free or cued recall or recognition conditions on the California Verbal Learning Test. Donders (1993) found the less severely injured group had better performance on figural recall than on story recall but it did not reach significance.

Overall the research indicates that significant differences do occur between memory scores and severity of injury. In particular the differences occurred in verbal memory. Severely head injured patients appear to be better able to recall verbal information than visually presented information. This may have occurred because verbal information has been over-learned and is less resistant to being forgotten. Those children with more severe injuries are able to recall less information than either less severely injured children or normal control subjects. Children with severe head injuries appear to do better on immediate recall tasks indicating that Type I processing is occurring. Type II processing occurs with delayed recall. Children with severe injuries either have difficulty attaining the depth of processing needed to place the information in long-term memory or have difficulty retrieving information that has been placed in long-term memory.

It was hypothesized that children who are 1 year or more post injury would perform significantly better than those who are 6 months or less post injury. A significant difference was not found in this sample. Most of the research does not mention time since accident as a variable. However, Levin, High et al. (1988) did find that at 1 year post injury severely injured children had impaired visual recognition memory when compared to less severely injured patients or control subjects. Severely injured adolescents had impaired verbal memory at the baseline assessment and at 1 year post injury when compared to less severe injuries or control subjects (Levin, High et al. 1988). Similar results were found by Levin, Eisenberg, Wigg and Kobayashi (1982). Severely injured children had impaired verbal memory when compared to less severely injured children or normal control subjects. Previous research does not support the findings of the present study. This may be due to the sample size. Both of the Levin studies had sample sizes at least twice the size of the one used for the present study.

It was hypothesized that older children would perform significantly better than younger children. A significant age difference was not found for the WMS-R variables. Most research does not report findings for age differences. In many studies a large age range was used without breaking
down the sample into smaller age groups. However, Lee (1995) did find significant increases in memory on the WMS-R for children in the normative database.

It was hypothesized that there would be a gender difference. The present study did not find gender differences and most of the published research does not report gender differences.

Intelligence

This section, like the previous one, focuses on Hypotheses 4 to 7. These hypotheses investigate whether there are significant differences between IQ and the variables of severity, time since accident, age and gender of the child.

The present study found no significant differences in the IQ scores depending on the variables of severity, time since accident, age and gender. Generally the IQ scores obtained by the clinical population were in the average range, but some of the IQ scores were below the average range. These results are comparable to the findings of other research (Levin, Eisenberg, Wigg & Kobayashi, 1982; Paniak, Silver, Finlayson

& Tuff, 1992). The IQ scores obtained in the present study often had a large standard deviation, indicating that there was a large variation in the scores. Some scores in each age level did reach the average range. Jaffe et al. (1993) noted that severely and moderately injured children generally function in the normal range but severely injured children have a greater variability in scores, as indicated by the standard deviations obtained.

Capruso and Levin (1992) reported that the verbal subtests measure semantic knowledge, which is often over-learned and more resistant to brain damage. PIQ is often impaired due to the demands of motor speed, manipulation and visual perception. Many of the subtests are novel tasks that demand active problem solving rather than responding with over-learned and rote knowledge (Capruso & Levin, 1992).

Chadwick, Rutter, Brown, Shaffer and Traub (1981) found that at the initial assessment and 1 year after injury children with a severe head injury obtained greater VIQ than PIQ scores by an amount that was significantly greater than the control group. This find. s not support the results in the present study in which PIQ impairment was not generally found. In general PIQ was often greater than VIQ. The Verbal-Performance (V-P) discrepancy ranged from 3.5 points to 19 points. Only at ages 9, 15 and 16 years did the V-P discrepancy favour VIQ by 7.66 points, 1.5 points and 10 points respectively.

In a sample of adults with closed head injuries a statistically significant V-P discrepancy was found. PIQ scores less than VIQ scores, by 10 or more points, were obtained by 27% of the sample and 11% had PIQ scores of 10 or more points above VIQ scores (Paniak, Silver, Finlayson & Tuff, 1992).

It was hypothesized that a significant difference in IQ scores would be found due to severity of injury. No significant differences between IQ scores and severity of injury were found when T-tests were performed. Those patients with extremely severe injuries did obtain lower scores than patients with very severe injuries but not significantly lower. This result could be due to the large standard deviations that occurred with each severity level. This finding was not supported by the literature.

Jaffe et al. (1992) found that PIQ scores for moderately and severely injured children were lower than those of controls, with the greatest magnitude of deficit occurring for the most severely injured. VIQ scores for all severity levels were within normal limits. Levin and Eisenberg (1979) concluded there were statistically significant differences in VIQ scores based on severity of injury, as moderately injured patients obtained higher scores than severely injured patients. Levin, Goldstein, High and Eisenberg (1988) also concluded that the more severe the injury, the greater the global cognitive impairment. The literature does not support the findings of the present study. This may have occurred because the comparison in the literature is between moderate and severe injuries, while the present study is comparing two different levels of severe injuries. It may be that the distinctions between very severe and extremely severe are minimal when focusing on the IQ scores.

It was hypothesized that a significant difference in IQ scores would be found due to time since the accident. This result was not found in the sample. Previous research has found similar results. Nonsignificant differences may have been found because there is no set rate of recovery from head injury. Each individual recovers at their own speed. Recovery time may also depend on the severity of the injury.

It was hypothesized that a significant difference in IQ scores would be found due to age. The present study found nonsignificant age differences which may have been due to the small number of subjects in each age group. Most of the research does not report age differences. Those that do, have generally found no significant differences in an adult population. Research with children has also found nonsignificant results.

It was hypothesized that a significant difference in IQ scores would be found due to gender. This study did not find any gender differences. Most of the research does not report gender differences possibly because twice as many males as females experience closed head injuries.

Overall, the findings of this study indicated that there is a relationship between intellectual ability and memory impairment, particularly for FSIQ and VIQ but less so for PIQ. A significant relationship between IQ and memory was also found for severity of injury, time since accident, age and gender. Significant differences were not found for IQ scores and the variables of severity, time since accident, age and gender. When comparing the WMS-R variables and severity, a significant difference was found for Logical Memory and not Visual Reproduction. Time since accident, age and gender did not result in significant differences for the WMS-R variables.

Implications for Education

Previous research has shown that memory impairment is greater than intellectual impairment for both adults and children, a finding that has received some support in this study. Head injury has many implications for education. Besides affecting memory and intellectual capabilities, head injury affects such abilities as attention, concentration, problem solving, language, academic skills and behaviour. Head injured children may be easily distracted by noise or activities in the classroom. Furthermore, a subtle decrease in the speed of processing information leads to difficulty keeping pace with classroom discussions, instructional presentations and assigned class work (Fay et al., 1994). Traditional teaching methods emphasize rapid assimilation of new information, immediate placement into memory, and instant retrieval of verbal information (Fay et al., 1994). Obrzut and Hynd (1987) reported that brain damage in children impairs their ability to acquire knowledge in the way that it is presented in the schools and therefore the children are unable to master the skills taught in school.

It is estimated that nearly half of the head injured population suffers from residual memory deficits. Severe head injuries acquired in childhood may result in the delayed appearance of impairments in verbal learning and memory until adolescence, when mnemonic strategies usually develop (Levin, High, et al., 1988). Strategies such as rehearsal or elaboration, which are examples of Type II processing, do not appear or are delayed in their appearance. If Type II processing is impaired then the information is not processed adequately to remain intact in long-term memory. In some cases the information is processed but difficulties occurring the retrieval process.

Achievement and intellectual tests that are given under ideal conditions do not adequately measure the child's abilities. These tests often measure over-learned skills that can be easily recalled (Mira, Tucker & Tyler, 1992). Fay et al. (1994) noted that although children perform at the 25th-75th percentile on standardized intellectual and achievement tests, they are still at a high risk for educational problems. Head injured children may obtain normal results on these standardized tests when compared to the published norms, but when compared to their peers head injured children appear to be delayed.

Jaffe et al. (1993) found a statistically significant correlation between decreasing performance on achievement tests and increasing severity of injury. Skills that were mastered before injury may not remain intact, while others may simply not emerge. In general, math skills are severely impaired immediately after a head injury. Computational skills are often regained quickly but deficits in math reasoning and problem solving may persist (Mira, Tucker & Tyler, 1992). In reading, the recognition of words often returns quickly but reading comprehension problems are common (Mira, Tucker & Tyler, 1992).

A neuropsychological assessment will detect subtle deficits that may be missed when using standardized achievement and intellectual tests. This information is useful in the rehabilitation of the head injured child. Rehabilitation is the process in which a child is helped to attain their premorbid or close to premorbid level of functioning. It involves facilitating spontaneous recovery, relearning old skills and learning new skills.

Rehabilitation can occur through direct retraining of the residual cognitive functions, using carefully targeted drills and practice. This technique can be used for basic tasks, such as selective attention or higher level tasks, such as logical reasoning (Szekeres, Ylvisaker & Holland, 1985). Compensatory strategies are used to compensate for deficits and to enhance neuropsychological strengths. These strategies have the benefit of increasing the motivation and cooperation of the child in the rehabilitation process (Begali, 1992). The emphasis of late stage cognitive rehabilitation is on teaching the child how to integrate the skills they have learned and generalize these skills to new settings, such as the classroom (Haarbauer-Krupa, Henry, Szekeres & Ylvisaker, 1985).

There are many areas of the cognitive domain that will be affected by head injury, such as discrimination, categorization, sequencing and memory. Discrimination is the ability to differentiate between two or more stimuli. Tasks to improve this ability include connecting the dots to form patterns and visually matching objects to objects, letters to letters, words to words and words to objects (Adamovich, Henderson & Auerbach, 1985). Categorization tasks require the child to be able to identify the category, recognize subtle differences and then switch sets (Adamovich, et al., 1985). Strategies to help children with such tasks include sorting objects into general categories and then into more specific categories, or sorting objects according to various traits (Adamovich et al.). Sequencing is the ability to arrange items in an order. Sequencing strategies include visually or auditorally sequencing words in which the letters are scrambled, or following directions with increasing complexity (Adamovich et al.).

Memory therapy can be undertaken to decrease the amount of forgetting that can occur. Memory therapy attempts to teach memory impaired individuals how to use specific compensatory strategies. Internal strategies include creating a rhyme to remember a set of related information, verbally repeating information, chunking or creating a visual sequence of the steps that lead up to the event, using self-talk and rehearsing information (Begali, 1992). External aids, which are used to supplement internal storage mechanisms, include lists, diaries and microcassette recorders (Begali, 1992).

Using information from the neuropsychological assessments, a decision about academic placement can be made and an Individualized Educational Program (IEP) can be developed to focus on remediation of deficit skills that will interfere with the educational process (Begali, 1992). Many head injured children are placed in special education classrooms but not all head injured children require this type of classroom. No two injuries manifest in the same neurobehavioural consequences, pattern or degree of recovery, therefore, each child needs to be considered individually for the proper educational placement. The educational program, whether a special education class or regular classroom, must be flexible enough to allow for frequent modifications to the program as the child continues to recover (Begali, 1992).

Guidelines for Teachers

Teachers often have little or no training about the effects of head injury on children's academic skills. Professional training and development programs should be used so that teachers can be made aware of the similarities and differences between students with closed head injury and those with other handicaps and of the impact of impairments on learning and performance (Blosser & DePompei, 1991). Information about educational program decision making and development needs to be included along with consultation and collaboration between the school, rehabilitation professionals and the family (Blosser & DePompei, 1991).

Students who have suffered a head injury benefit from having a highly structured classroom, since this helps to decrease the auditory and visual distraction that can occur (Blosser & DePompei, 1991). Students also benefit from a low student-teacher ratio and from having a teacher's aide in the classroom (Telzrow, 1987). Due to decreased speed in processing information, many students may require more time to complete class assignments or tests. They may require oral exams or multiple choice exams (Begali, 1992). The head injured student would also benefit from a multisensory approach to teaching that includes both visual and verbal instructions because children with head injuries are generally better able to recall information that is presented verbally. Audiotaping the instructions would allow the student to listen to them as often as needed. In addition, repeating new material and tasks, as well as keeping the teaching activities short and simple, should be encouraged in order to help the student learn the new information (Burns, Cook & Ylvisaker, 1988). Information can be better retained if it is made relevant to the child and matches the child's learning style (Burns, et al., 1988).

It is hoped that this study will provide information that will lead to a better understanding of the problem of head injury, and in particular the relationship between memory impairment and intellectual ability. By using the WMS-R in a school aged population new information can be gained in the areas of verbal and visual memory. This may lead to the development of intervention programs for children with brain injuries. This information could also be used to prepare the school and the child for re-entry into the classroom and would provide information that is needed to develop an individualized educational program for the child.

Recommendations for Future Research

The present study has implications for future research using the WMS-R on pediatric populations. The present study investigated the relationship between intellectual ability and memory for children aged 9-18 years who have experienced a closed head injury. It involved the use of the WMS-R subtests Logical Memory and Visual Reproduction. Levin, High, et al. (1988) noted the lack of research concerning the long-term effects of closed head injury on memory in children and adolescents. Even fewer studies have been conducted in which the focus has been intellectual recovery and memory functioning after head injury in children (Levin, Eisenberg & Miner, 1983).

Further research on memory using the WMS-R subtests Logical Memory and

Visual Reproduction should be conducted on pediatric populations with various brain injuries. Research that focuses on intellectual ability and memory functioning should be undertaken to increase the knowledge in this area. In addition, studies similar to this one but with a larger sample size, or studies using a comparison of clinical and control groups could also be undertaken.

Longitudinal studies should be undertaken to examine the changing relationship between intellectual ability and memory over time. These studies could start after the resolution of PTA and continue at yearly intervals for a period of several years. Further research could investigate the relationship over time, focusing on severity and age of the child at time of accident. This could provide further information that could be used to develop rehabilitation programs or to aid in educational planning.

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Appendix A

Correlations between Intelligence Subtest scores and WMS-R Variables

Table A1

Correlation between Intelligence subtest scores and WMS-R variables (n=27)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.3283	.2031	-.0212	.4511*	.1660	.0949
Sim	.4284*	.3094	-.0728	.3600	.2133	.1586
Arith	.0540	-.0091	-.0565	.2133	.1712	.1872
Voc	.4608*	.3646	.0369	.4813*	.2840	.2334
Comp	.3788*	.4013*	.1872	.2950	.1711	.1756
Dig Sp	.2977	.1645	-.1027	.3070	.3087	.2797
Pic Comp	.1991	.1936	.1183	.5340*	.2548	.1602
Pic Arr	.4083*	.3936*	-.0455	.4432*	.1434	.0783
Bl Des	.1159	.0632	-.0705	.5878**	.3412	.2080
Ob Ass	.3536	.3933*	.2131	.7624***	.5162	.3714
Cod/DigSy	.1913	.1968	-.0598	.1975	.2604	.2963

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
* $p < .05$
** $p < .001$
*** $p < .0001$

Table A2

Correlation between Intelligence subtest scores and WMS-R variables for Very Severe Injury (n=14)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.1103	-.0666	-.4735	.5342*	-.0121	-.2097
Sim	.2026	.0800	-.3091	.6264*	.2512	.0898
Arith	-.0809	-.2238	-.3991	.0807	-.1185	-.1000
Voc	.3635	.3056	-.0809	.5400*	.0780	-.0649
Comp	.1778	.1101	-.3104	.0151	-.4101	-.4375
Dig Sp	.4575	.2867	-.3504	.6825*	.3691	.1629
Pic Comp	.0410	-.0643	-.2077	.7358*	.3674	.1712
Pic Arr	.1757	.2538	.1271	.2796	.0298	-.0314
Bl Des	-.0978	-.1944	-.3265	.4987	.3026	.1971
Ob Ass	-.2826	.2733	.0137	.7256*	.4914	.3610
Cod/DigSy	-.2875	-.3072	-.1676	.2076	-.0873	-.1254

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
* $p < .05$

Table A3

Correlation between Intelligence subtest scores and WMS-R variables for Extremly Severe Injury (n=10)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.6087	.4146	.0926	.6457*	.3331	.2331
Sim	.6706*	.4261	-.0718	.2336	.1107	.1110
Arith	.3260	.2631	.0058	.4659	.4739	.4031
Voc	.6910*	.5598	.0803	.6969*	.5301	.3896
Comp	.5587	.7075*	.3732	.4805	.5995	.5308
Dig Sp	.7145	.5549	-.0130	.4875	.5670	.4718
Pic Comp	.4357	.5151	.2052	.5043	.2403	.2030
Pic Arr	.8480	.5445	-.2082	.5335	.1950	.1373
Bl Des	.4182	.3341	-.0418	.6869*	.3964	.2137
Ob Ass	.3829	.4302	.2682	.8310*	.4814	.3306
Cod/DigSy	.6305	.5624	-.1263	.1567	.3181	.3811

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
*$p < .05$

Table A4

Correlation between Intelligence subtest scores and WMS-R variables for less than 6 months since accident (n=15)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.2400	.0456	-.1350	.3478	.1132	-.0115
Sim	.3260	.2074	.0337	.2478	.4394	.4178
Arith	-.2022	-.1905	-.1005	.0403	.1245	.1888
Voc	.3245	.1322	-.0086	.2819	.4092	.3701
Comp	.4608	.3981	.2551	.1303	.3448	.3756
Dig Sp	-.0005	-.0802	-.0727	.1055	.3803	.4342
Pic Comp	.0323	.0205	.0234	.3023	.3752	.3498
Pic Arr	-.0114	-.0378	-.0065	.3428	.2730	.1940
Bl Des	-.1176	-.1569	-.0922	.5469	.5089	.3633
Ob Ass	.1553	.0626	-.0568	.7029	.7109	.5229
Cod/DigSy	-.2195	-.0578	.2236	-.1936	.2308	.3894

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Table A5

Correlation between Intelligence subtest scores and WMS-R variables for More than 1 year since accident (n=12)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.3711	.2949	.0489	.5286	.1788	.1290
Sim	.4778	.3616	-.1206	.4527	.0760	.0217
Arith	.3169	.2085	-.0142	.5243	.2411	.1837
Voc	.5561	.5368	.0943	.6618*	.1269	.0671
Comp	.3635	.4134	.1503	.4531	.0600	.0718
Dig Sp	.7230	.5643	-.1523	.6776	.2100	.0657
Pic Comp	.3168	.3125	.1405	.7999	.2556	.1361
Pic Arr	.6288*	.6465*	-.0842	.5662	.0990	.0624
Bl Des	.3474	.3047	-.0771	.6994*	.1601	.0763
Ob Ass	.5101	.6556*	.3822	.8502**	.3647	.2920
Cod/DigSy	.4082	.3603	-.2078	.5450	.2839	.2287

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
* $p < .05$
** $p < .0001$

Table A6

Correlation between Intelligence subtest scores and WMS-R variables for Children aged 9-13 years (n=10)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.0438	-.0269	-.0445	-.3079	-.4254	-.3115
Sim	.4185	.3558	.1648	.1322	-.2062	-.3411
Arith	.3841	.1700	-.1305	.2264	.3948	.3185
Voc	.3080	.1061	-.1343	.1862	-.0630	-.1746
Comp	-.4007	-.1651	.0108	.0841	-.4155	-.5245
Dig Sp	.5284	.1080	-.2529	-.0733	.2088	.2318
Pic Comp	.5389	.3818	.0380	.7463	.3528	.0477
Pic Arr	.0097	.1864	.1716	.4070	.2201	.0339
Bl Des	.0536	-.0492	-.1651	.2048	.1528	.0513
Ob Ass	.2316	.3230	.2341	.7066	.3695	.0823
Cod/DigSy	.1248	.3441	.4623	.1461	.1206	.1072

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Table A7

Correlation between Intelligence subtest scores and WMS-R variables for Children aged 14-18 years (n=17)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.3783	.2456	-.0268	.6476*	.2905	.2015
Sim	.6183	.4981*	-.0411	.6541*	.4303	.3340
Arith	.0592	.0261	-.0083	.3181	.1696	.1607
Voc	.6446*	.5931*	.1316	.7678**	.4750	.3977
Comp	.6161*	.6466*	.2729	.4901*	.3585	.3609
Dig Sp	.3679	.3064	-.0277	.6806*	.5026	.3725
Pic Comp	.2103	.2418	.1779	.6143*	.2867	.2056
Pic Arr	.5496	.5194*	-.0520	.5509*	.1621	.0967
Bl Des	.1396	.1007	-.0556	.7645**	.4103	.2667
Ob Ass	.4131*	.4444	.2224	.8455**	.5851*	.4948*
Cod/DigSy	.3945	.3923	-.0476	.4650*	.4445	.4085

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
* $p < .05$
** $p < .0001$

Table A8

Correlation between Intelligence subtest scores and WMS-R variables for Females (n=10)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.6100	.6230	.5937	.7050*	.3266	.2136
Sim	.4892	.5430	.6174	.8213*	.6793*	.5255
Arith	-.1176	-.1440	-.0056	.2578	-.0945	-.0779
Voc	.5841	.5925	.6073	.9136***	.6010	.4586
Comp	.8577*	.8629**	.7144*	.6112	.1726	.1797
Dig Sp	.1423	.1120	.1923	.6928*	.5173	.3835
Pic Comp	.2254	.2212	.3391	.8002*	.4214	.2733
Pic Arr	.5094	.6031	.6109	.6955*	.4741	.4062
Bl Des	.4586	.4195	.2983	.8156*	.4854	.2767
Ob Ass	.5823	.5979	.5207	.9087***	.6451	.4299
Cod/DigSy	.3995	.5562	.7988	.6817*	.4173	.4346

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
* $p < .05$
** $p < .001$
*** $p < .0001$

Table A9

Correlation between Intelligence subtest scores and WMS-R variables for Males (n=17)

	LM I	LM II	LMSS	VR I	VR II	VRSS
Info	.2557	-.0158	-.3197	.2023	.0817	.0384
Sim	.3762	.0799	-.4017	-.0999	-.0826	-.0817
Arith	.3004	.2234	-.1645	.1205	.3064	.3458
Voc	.4285	.2189	-.2458	.0287	.0922	.0994
Comp	-.0319	-.0704	-.0430	-.0209	.1816	.1794
Dig Sp	.4113	.2297	-.2549	.1033	.2628	.2736
Pic Comp	.2395	.2315	.0022	.2584	.1597	.0986
Pic Arr	.3242	.1689	-.4052	.1641	-.0937	-.1676
Bl Des	.0532	-.0462	-.2778	.4255	.3026	.2044
Ob Ass	.1510	.1663	.0492	.5702*	.4621	.3617
Cod/DigSy	.0760	-.0317	-.3418	-.1339	.1910	.2330

Info = Information
Sim = Similarities
Arith = Arithmetic
Voc = Vocabulary
Comp = Comprehension
Dig Sp = Digit Span
Pic Comp = Picture Completion
Pic Arr = Picture Arrangement
Bl Des = Block Design
Ob Ass = Object Assembly
Cod/DigSy = Coding/Digit Symbol

Two-tail significance
*$p < .05$

Appendix B

T-Tests for the Intelligence Scales Subtests

Table B1

T-test for the Verbal Subtest Information

		Mean	SD	df	T-Value	p
Severity	Very Severe	22.857	19.214	22	1.54	.137
	Extremely Severe	15.000	12.957			
Time Since Accident	< 6 months	7.3333	2.160	25	.69	.497
	> 1 year	6.6667	2.871			
Age	9-13 years	6.9000	1.729	25	-.22	.830
	14-18 years	7.1176	2.870			
Gender	Male	7.5294	2.348	25	1.37	.182
	Female	6.2000	2.573			

Table B2

T-test for the Verbal Subtest Similarities

		Mean	SD	df	T-Value	p
Severity	Very Severe	9.6429	3.433	22	1.42	.170
	Extremely Severe	7.6000	3.534			
Time Since Accident	< 6 months	8.8000	2.704	25	-.15	.883
	> 1 year	9.0000	4.264			
Age	9-13 years	10.500	2.415	25	1.99	.058
	14-18 years	7.9412	3.614			
Gender	Male	9.7059	2.098	25	-.36	.724
	Female	9.2000	4.050			

Table B3

T-test for the Verbal Subtest Arithmetic

		Mean	SD	df	T-Value	p
Severity	Very Severe	7.5714	2.174	22	-.26	.801
	Extremely Severe	7.8000	2.150			
Time Since Accident	< 6 months	9.2000	2.808	25	.48	.633
	> 1 year	7.7500	1.765			
Age	9-13 years	8.6000	1.776	25	1.01	.322
	14-18 years	7.6471	2.644			
Gender	Male	8.8235	2.243	25	2.60	.015*
	Female	6.6000	1.955			

Two-tail significance * $p < .05$

Table B4
T-test for the Verbal Subtest Vocabulary

		Mean	SD	df	T-Value	p
Severity	Very Severe	7.4286	1.697	13.06	.69	.503
	Extremely Severe	7.6000	3.020			
Time Since Accident	< 6 months	7.7333	2.187	25	1.17	.251
	> 1 year	6.6667	2.535			
Age	9-13 years	8.1000	1.969	25	1.45	.160
	14-18 years	6.7647	2.488			
Gender	Male	7.4706	2.183	25	.60	.555
	Female	6.9000	2.762			

Table B5

T-test for the Verbal Subtest Comprehension

		Mean	SD	df	T-Value	p
Severity	Very Severe	8.4286	3.056	22	1.44	.165
	Extremely Severe	6.6000	3.095			
Time Since Accident	< 6 months	7.4667	2.625	25	-.46	.651
	> 1 year	8.0000	3.438			
Age	9-13 years	8.7000	1.829	25	1.36	.185
	14-18 years	7.1176	3.371			
Gender	Male	7.4706	2.601	25	-.53	.603
	Female	8.1000	3.604			

Table B6

T-test for the Verbal Subtest Digit Span

		Mean	SD	df	T-Value	p
Severity	Very Severe	7.8333	2.368	18	-.79	.436
	Extremely Severe	9.2500	5.523			
Time Since Accident	< 6 months	8.8571	4.240	21	.39	.702
	> 1 year	8.2222	3.032			
Age	9-13 years	9.6667	4.416	21	1.09	.288
	14-18 years	7.9286	3.245			
Gender	Male	9.6429	4.199	21	1.72	.100
	Female	7.0000	2.291			

Table B7

T-test for the Performance Subtest Picture Completion

		Mean	SD	df	T-Value	p
Severity	Very Severe	9.2857	2.785	22	.31	.760
	Extremely Severe	8.0000	3.315			
Time Since Accident	< 6 months	8.4000	2.384	25	-1.37	.183
	> 1 year	9.9167	3.370			
Age	9-13 years	9.8000	2.251	25	.99	.329
	14-18 years	8.6471	3.220			
Gender	Male	9.4118	2.717	25	.78	.442
	Female	8.5000	3.274			

Table B8

T-test for the Performance Subtest Picture Arrangement

		Mean	SD	df	T-Value	p
Severity	Very Severe	9.7857	3.577	22	.70	.490
	Extremely Severe	8.7000	3.945			
Time Since Accident	< 6 months	8.6000	2.995	25	-.88	.369
	> 1 year	9.8333	4.303			
Age	9-13 years	9.8000	2.616	25	.71	.483
	14-18 years	8.7647	4.116			
Gender	Male	9.0000	3.062	25	-.27	.767
	Female	9.4000	4.575			

Table B9

T-test for the Performance Subtest Block Design

		Mean	SD	df	T-Value	p
Severity	Very Severe	9.2143	2.577	22	.01	.992
	Extremely Severe	9.2000	4.158			
Time Since Accident	< 6 months	9.1333	3.502	25	-.30	.767
	> 1 year	9.5000	2.646			
Age	9-13 years	9.3000	2.830	25	.00	.996
	14-18 years	9.2941	3.331			
Gender	Male	10.1765	2.963	25	2.04	.052
	Female	7.800	2.860			

Table B10

T-test for the Performance Subtest Object Assembly

		Mean	SD	df	T-Value	p
Severity	Very Severe	8.8571	3.325	22	.92	.370
	Extremely Severe	7.6000	3.307			
Time Since Accident	< 6 months	8.1333	3.137	25	-.43	.674
	> 1 year	8.6667	3.367			
Age	9-13 years	8.3000	3.164	25	-.09	.932
	14-18 years	8.4118	3.299			
Gender	Male	8.4118	2.399	12.25	.07	.942
	Female	8.3000	4.373			

Table B11

T-test for the Performance Subtest Coding/Digit Symbol

		Mean	SD	df	T-Value	p
Severity	Very Severe	8.3571	2.706	22	2.86	.009*
	Extremely Severe	5.1000	2.807			
Time Since Accident	< 6 months	7.3333	2.969	25	.13	.897
	> 1 year	7.1667	3.664			
Age	9-13 years	9.1000	2.025	25	2.49	.020*
	14-18 years	6.1768	3.358			
Gender	Male	7.1765	3.414	25	-.17	.866
	Female	7.4000	3.062			

Two-tail significance * $p < .05$

Appendix C

Means and Standard Deviations for the Subtests on the Intelligence Scales

Table C1

Means and Standard Deviations for the Verbal Subtests

Age		Info	Sim	Arith	Voc	Comp	DigSp
9	Mean	8.33	9.67	7.67	7.67	9.00	9.00*
(n=2)	SD	1.53	1.15	2.52	3.06	2.65	5.66
10	Mean	6.00	10.50	8.50	7.00	8.00	6.00
(n=2)	SD	.00	.71	.71	2.83	2.83	.00
11	Mean	6.50	14.50	8.50	9.50	10.00	10.00
(n=2)	SD	.71	.71	.71	.71	.00	.00
12	Mean	5.00	8.50	10.50	8.50	7.50	15.00
(n=2)	SD	1.41	2.12	2.12	.71	.71	5.66
13	Mean	7.00	8.00	8.00	6.50	8.50	7.00
(n=2)	SD	2.83	1.41	.00	2.12	.71	.00
14	Mean	8.67	8.83	9.17	7.00	7.50	8.00
(n=6)	SD	3.33	4.07	3.06	2.28	4.04	3.56
15	Mean	7.00	8.50	6.00	7.00	5.25	6.00**
(n=4)	SD	3.56	5.69	2.58	4.32	3.77	2.00
16	Mean	5.00	5.50	5.50	6.00	8.00	6.00
(n=2)	SD	.00	.71	.71	1.41	5.66	.00
17	Mean	7.50	6.50	8.50	7.00	7.50	12.00
(n=2)	SD	71	.71	2.12	2.83	2.12	4.24
18	Mean	5.50	8.50	7.50	7.00	8.00	9.00
(n=2)	SD	2.12	2.12	2.12	1.41	1.41	4.24

* n=2   ** n=3

Table C2

Means and Standard Deviations for the Performance Subtests

Age		Pic Com	Pic Arr	Bl Des	Ob Ass	Cod/DigSym
9	Mean	7.00	7.67	7.33	5.33	9.67
(n=2)	SD	1.00	3.06	3.79	2.08	1.53
10	Mean	9.50	9.50	10.50	9.00	9.00
(n=2)	SD	.71	2.12	2.12	4.24	4.24
11	Mean	12.00	11.50	9.00	11.00	8.50
(n=2)	SD	1.41	.71	1.41	4.24	2.12
12	Mean	11.50	12.00	11.50	9.50	8.00
(n=2)	SD	5.11	2.83	3.54	.71	1.41
13	Mean	8.50	8.00	9.00	8.50	11.50
(n=2)	SD	3.54	1.41	.00	.71	.71
14	Mean	10.50	9.67	10.33	9.50	5.83
(n=6)	SD	2.95	4.63	2.66	2.59	4.26
15	Mean	7.25	7.25	7.50	7.75	4.25
(n=4)	SD	3.10	5.12	3.00	5.12	2.22
16	Mean	5.50	6.00	5.00	4.00	5.00
(n=2)	SD	.71	2.83	.00	2.83	.00
17	Mean	11.00	8.50	14.50	10.00	7.50
(n=2)	SD	4.24	.71	2.12	.00	2.12
18	Mean	8.00	13.00	9.00	9.00	8.00
(n=2)	SD	2.83	2.83	.00	.00	2.83