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PREMATURE BIRTH AND LEARNING DISABILITIES: A NEUROPSYCHOLOGICAL INVESTIGATION

BY ©

DONALD SUNIL MASSEY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled **PREMATURE BIRTH AND LEARNING DISABILITIES: A NEUROPSYCHOLOGICAL INVESTIGATION** submitted by **DONALD SUNIL MASSEY** in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** in **SCHOOL PSYCHOLOGY**.

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March 11, 1994

Dedicated to my wife Valerie, and my daughter Ashleigh

born prematurely at 27 weeks and 890 grams

and to my parents Thomas & Persis

for their support and encouragement

in making this possible

The author also wishes to acknowledge the assistance of

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for their willingness to participate

in this study

ABSTRACT

The study involved a neuropsychological investigation of a sample of children aged 9 - 14 with Premature birth histories (<2500 grams and/or <37 weeks gestation; n = 32) and a sample of normal-birthweight Siblings (Control) aged 9 -14 (>2500 grams and/or >37 weeks gestation; n = 8), using the Halstead-Reitan Neuropsychological Test Battery for Older Children (HRNB-C), WRAT-R, WISC-R, Bender-Gestalt, SIDAC, and Structured Interview. The aim of the study was to determine the extent and nature of Learning Disabilities including any differences in brain function, intellectual, academic, visual-motor, and behavioral deficits, for both groups (Prematures vs. Siblings) as well as within Prematures (Very Low Birthweight or VLBW <1500 grams, n = 12; Low Birthweight or LBW 1500 - 2500 grams, n = 20). It was hypothesized that both groups would differ on the above variables with the Prematures showing more impaired performance in general. Differences between the VLBW and LBW Prematures were also hypothesized. The results indicated that Prematures (n = 32) differed significantly (lower scores) from the Sibling Controls (n = 8) for FSIQ (p = .009) and PIQ (p = .006), but not VIQ (p = .055). VLBW / LBW Prematures, and Siblings differed significantly from each other for FSIQ (p = .05), and PIQ (p = .02), but not VIQ (p = .06). Prematures differed from Siblings on all WRAT-R subtests (lower scores), contained all the LD sample; and required more special education (56%) compared to Siblings (0%; p = .004). A higher proportion of VLBW Prematures (25%) were classified as Arithmetic LD (p = .02), compared to LBW Prematures (0%), however, no significant differences were noted between these groups for Global LD (VLBW = 16.6%; LBW = 24%) or Language LD (VLBW = 16.6%; LBW = 30%). Prematures showed more impaired neuropsychological performance on the HRNB-C (p = .000), compared to Siblings and VLBW / LBW subgroups. Prematures showed more impaired (78% abnormal) scores on the Bender-Gestalt (p = .000) compared to Siblings (0%), and more indicators of psychopathology on the SIDAC (p = .000). The results suggested that Learning Disabilities are associated with Prematures, possibility due to early destruction and/or dysfunction of cerebral white matter associated with right cerebral hemisphere disorders as noted by Rourke's Nonverbal Learning Disability model (1982; 1987;1988).

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

CHAPTER I

INTRODUCTION

Premature Birth and Learning Disabilities

Advances in medical technology have lead to a significant improvement in health care services for children and adults worldwide. A plethora of illness and diseases have virtually disappeared or reduced to very manageable levels. Medical technology has also improved childhood mortality and morbidity due primarily to advances in the field of neonatology, a branch of medicine specializing in the care of neonates. These advances have made it possible for children to survive the birth process particularly if they arrive earlier than expected. Children who arrive early are referred to as Prematures based on their birthweight (< 2500 grams) and/or their gestational period (< 37 weeks). However, increased survival rates for premature infants has also resulted in a host of accompanying medical complications which are known to cause significant difficulties in the quality of survival of these children. The quality of survival can vary as some children appear to be unaffected in latter life while significant others grow up with considerable handicaps.

Premature birth leads to early exposure of the infant's sensory systems to the extrauterine environment and all organ systems may be vulnerable to trauma during the peri- and postnatal periods. Medical complications are therefore the norm for children in this population and may lead to subsequent developmental insult. Furthermore, medical intervention designed to treat these complications may lead to iatrogenic or "treatment-caused" difficulties which can also affect development. These iatrogenic factors often point to "therapeutic disasters" in the history of medical care and treatment and some researchers provide a warning from that every innovation is not necessarily an advance, nor is apparently well-formulated treatment a guarantee of safety or efficacy (Avery, 1987; Britton, Fitzhardinge & Ashby, 1981; Stavis & Krauss, 1980). These factors are often cited as contributing to the etiology of not only physiological disorders but also more complex neurobehavioral and developmental deficits including Learning Disabilities.

A review of the literature indicates that children with premature birth histories appear to be significantly more at risk for developing learning problems as a result of either subtle or more pronounced brain impairment and/or dysfunction (Koop & Krakow, 1983). Since most problems in learning can only be identified once a child enters school, the "latent" effects of early (subtle) neurodevelopmental insult are often not identified clearly and frequently fall under the "developmental difficulties of unknown origin" category. As a result, parents and educators are often not appraised of the potential long-term effects of these problems since most medical assessments have resulted in a diagnosis implying that the child is simply "immature", or a prognosis that he or she will "grow out of it". In many cases however, these children do not outgrow their difficulties and require a great deal of academic remediation. Early identification of children at risk academically has been the ultimate goal of research in applied psychology. It has led to the development of a number of psychometric assessment tools and procedures that have successfully identified many groups of children at risk - including the largest of these groups, children with Learning Disabilities.

Nature of the Problem

With advances in neonatology, it is hoped that some answers to medical concerns about outcome may be found. In order to keep pace with medical research, commensurate efforts in pediatric psychology and education must be made as it is these fields which have traditionally been given the responsibility of remediating developmental difficulties. Developmental outcome for the premature child is of vital importance from an educational perspective since learning depends directly on intact sensory and intellectual processes, intricately mapped out over the course of early development. Any research investigating the extent to which conditions associated with preterm birth cause short and long-term developmental impairment is equally vital when one considers optimal outcome. Research investigating specific outcome with respect to learning would also be of great value to the fields of education, psychology, and medicine. Although some might argue that this area has been extensively examined, analysis has primarily been from a medical perspective for medical personnel, and the focus has been a description of more organic and overt disabilities. Little attention has been focussed on such subtle and covert disabilities such as Learning Disabilities which are often observed within this clinical population.

Many studies have neglected to examine the occurrence and nature of low-severity but high-incidence difficulties such as Learning Disabilities within this population. This is primarily due to the fact that the general focus of many studies has been on physical and/or overt developmental disabilities for younger children. In a few cases, the existence of Learning Disabilities has been documented using standard psycho-educational procedures which do not describe the specific nature of these disabilities with respect to brain-behavior relationships, or Learning Disability subtypes. This apparent "gap" in technical knowledge regarding the neuropsychological functioning of this population has not been well documented and requires closer investigation.

The current study evolved out of the authors own clinical work with school aged children with a variety of learning, developmental and/or behavioral deficits, when it was observed that Prematures represented a large proportion of these cases. On further examination, it was also noted that the pattern of learning and/or cognitive deficits manifested by children with premature birth histories was quite different when compared to other handicapped children with normal birthweight and that these differences frequently represented observable neuropsychological dysfunction in the case of the Prematures. A preliminary review of the literature and small pilot study conducted by the author indicated the need for further investigation of this group of children who show more subtle deficits such as Learning Disabilities using sibling controls and neuropsycholocial procedures as this had not been documented in the literature. It was hypothesized that children with premature birth histories are likely to have suffered subtle neurodevelopmental deficits that may make them more susceptible to Learning Disabilities. The premature birthweight group of children was also chosen as low birthweight is considered to be the most common risk factor in early life which accounts for 1.2% of all live births and is associated with both serious handicaps as well as relatively minor problems such as school failure (Drillen, 1964). Low birthweight is also the most frequently investigated risk factor for later developmental problems (Scott & Masi, 1979), and therefore shares a long research history at least from the medical point of view. A neuropsychological format was employed in order to determine if any subtle brain dysfunction could be identified in relation to LD and LD subtypes. Other disorders that are often noted to coexist among LD populations (ADHD, Conduct Disorders, etc) were also surveyed as well as a variety of other demographic variables including medical complications that these children may have sustained.

Recognizing that research establishing the connection between Learning Disabilities and premature birth would be a very complicated endeavor, this study sought to investigate the following general questions:

1. Do children with premature birth histories differ in intellectual ability from normal birthweight Siblings ?

2. Are there any patterns of cognitive deficits associated with premature birthweight children when compared to their normal birthweight Siblings ?

3. Is there a difference in cognitive performance for children with lower vs. higher birthweight within the premature birth group ?

4. Is premature birth associated with the development of Learning Disabilities ?

5. Do children with premature birth histories differ in academic achievement from normal birthweight Siblings ?

6. Do children with premature birth histories show more signs of Learning Disabilities compared to a group of Siblings with normal birthweight ?

7. Do children with premature birth histories show specific subtypes of Learning Disabilities compared to Siblings with normal birthweights?

8. Is there a difference in academic performance for children with lower vs. higher birthweight within the premature birth group ?

9. Is there a difference in subtypes of Learning Disability for children with lower vs. higher birthweight within the Premature group ?

10. Do children with premature birth histories differ in neuropsychological performance compared to Siblings with normal birthweights ?

11. Are there any patterns of neuropsychological brain dysfunction noted for children with premature birth histories compared to normal birthweight Siblings ?

12. Is there a difference in the neuropsychological performance between children with lower vs. higher birthweight within the Premature group ?

13. Do children with premature birth histories differ in visual-motor integration skills compared to Siblings with normal birthweights ?

14. Do children with premature birth histories differ in behavioral and/or emotional deficits compared to Siblings with normal birthweights ?

15. Do children with premature birth histories show specific patterns of psychopathology compared to their normal birthweight Siblings ?

The relationship if any, between premature birth and Learning Disabilities was conducted by examining a small group of children with premature birth history (N = 32 children between the ages of 9 - 14; birthweights < 2500 grams, gestation < 37 weeks), and comparing their performance to a group of normal Siblings (N = 8, ages 9 - 14, birthweights > 2500 grams, gestation > 37 weeks). Both groups of children were examined using selected neuropsychological measures to determine if the criteria for Learning Disabilities (including subtypes of LD) could be met more frequently or exclusively within the Premature group of children.compared to normal controls and published normative data. The aim of this descriptive confirmatory study was to evaluate these children on a variety of neuropsychological tasks (Halstead-Reitan Neuropsychological Test Battery for Older Children [ages 9 - 14], [HRNB-C]), as well as on tasks measuring academic achievement (Wide Range Achievement Test - Revised, WRAT-R), intellectual ability (Wechsler Intelligence Scale for Children - Revised, WISC-R), visual-motor integration (Bender Visual-Motor Gestalt Test, BVMGT), behavioral and emotional status (Structured Interview for the Diagnostic Assessment of Children, SIDAC), and general developmental and psychological functioning (Clinical Interview, CI), with respect to the extent to which they met the criteria for a Learning Disability (LD), including subtype analysis in accordance with the classification system advocated by Rourke (1985). The presence or absence of brain dysfunction for both groups of children was also assessed using the classification system outlined by Selz & Reitan (1979). In addition, the presence or absence of psychopathology for both groups of children was assessed based on the DSM-III criteria

Test score performance of the two groups of premature and non-premature children, as well as children within the Premature group with very low birthweight (VLBW) versus low birthweight (LBW) was compared statistically (t-test, Anova, Chi-square, Pearson correlation) in order to determine if they differed from each other on a variety of variables including academic achievement (WRAT-R Reading, Spelling, Arithmetic scores), Intellectual Ability (WISC-R Verbal, Performance, Full Scale scores), Neuropsychological performance (HRNB-C), visual-motor integration (BVMGT) and behavioral / emotional functioning (SIDAC). It was hypothesized that the Premature group would likely display lower intellectual ability including a pattern of lower Performance IQ compared to Verbal IQ, lower academic achievement, more indicators of a Learning Disability including subtypes of LD, more impaired neuropsychological performance including specific indicators of brain dysfunction, poorer performance in visual-motor integration, and more indicators of psychopathology, in comparison to the non-Premature group of Siblings who would likely not display any of these deficits. It was further hypothesized that children within the Premature group with very low birthweight (VLBW) would likely show more indicators of impaired performance on all the above variables compared to children within the premature birth group with higher birthweight (LBW).

It was hoped that this research would lend support to a growing body of knowledge that suggests that LD in addition to lower academic achievement in general is frequently observed among premature birthweight children when compared to normal birthweight children. It was further hoped that subtype analysis may shed further light on unique patterns that may be evidenced within this population of children compared to the published results on subtypes of other LD children. The fundamental objective of this research was to demonstrate that learning deficits resulting from cognitive and/or neuropsychological dysfunction tend to persist among children with premature birth histories well into the late childhood and early adolescent period and are likely related to factors connected to their specific birth history and condition of prematurity. Prior research in this field has not directly evaluated the neuropsychological performance of this older group of premature birthweight children. It is hoped that the following study will not only assist in the early identification of these children who appear to be at risk but also provide important information for clinicians and educators involved in the diagnosis and remediation for children with premature birth history.

In order to view the potential benefits of conducting this study, as well as to document the rationale for evaluating the specific needs of this particular population, a brief review of neurodevelopmental issues, medical complications, and research concerning neurodevelopmental outcome follows.

CHAPTER II

SELECTIVE REVIEW OF THE LITERATURE

Human Neurodevelopment and Neuropathology

In view of the complexity of the cortex and its prolonged development, it is reasonable to expect that normal cortical development could be disrupted by any number of events, particularly during the critical periods of brain growth and development. These include abnormalities in the normal genetic program of neural growth, influences of exogenous factors such as toxic substances or brain trauma resulting from anoxia, hemorrhage or other complications of premature birth, and nutritional or other environmental circumstances. If the brain is damaged during development, it is reasonable to suppose that its development might be fundamentally altered.

The human brain follows a general pattern of development, beginning as a neural tube, and gradually acquires the features of the adult brain. The basic neural tube surrounds a single ventricle where cells are generated along the ventricular wall and then migrate out to their proper location. During development, the cortex is composed of four embryonic regions or zones. These are transient features of early development as they either disappear or become transformed so that they are no longer identifiable in the adult nervous system. Sidman and Rakic (1973) have produced a summary of the timing and phases of cortical development and suggest approximately five developmental stages in neuronal development: the proliferation and migration of cells; the growth of axons and dendrites; synapse formation and loss; and myelin growth. Other processes continue on until late adolescence.

Two significant periods of rapid brain growth characterize the embryonic development of the human brain. A minor growth spurt occurs from approximately 10 to 18 weeks from gestation, followed by a major growth spurt occurring from about the fourth to fifth prenatal month to about the end of the fourth year of life (Dobbing & Sands,1973). The first period of brain growth is by far the most vulnerable to severe developmental disorders related to genetic and chromosomal defects, viral infections, and the effects of irradiation. During this period, most of the neurological sequelae are associated with hypoxic-ischemic and hemorrhagic lesions that occur in the newborn infant (Volpe, 1983).

The second period of brain growth is significantly longer and subject to a host of other potential disorders that may alter the pre-designed function of a variety of brain systems. For example, the nature of the cerebrovascular asymmetry is such that the left hemisphere is more likely to be affected sooner and to a greater extent than the right hemisphere which, some have argued, leads to developmental learning deficits particularly in language functioning (Carmon, Harishanu, Louringer, & Lavy,1972). Others have argued that the cerebral hemispheres develop at different rates and times (Thatcher, Walker, & Giudice, 1987), which may affect later function if injury occurs at crucial periods of development. For example, language regions of the left temporal lobe develop more slowly but ultimately reach greater size and complexity of organization (Benson, 1979). This longer period of growth may make these areas more vulnerable to disrupting lesions. Reversal of cerebral asymmetry including a wider right parieto-occipital region (measured by cranial computed tomography) has been shown in individuals with developmental dyslexia and verbal intellectual deficits (Hier, Le May, Rosenberger, & Perlo, 1978, Rosenberger & Hier, 1980; Hynd & Willis, 1988). These asymmetries could also result in language lateralization from the "normally dominant" left hemisphere to the right hemisphere that is structurally less suited to support language function (Gorelick & Swiontoniowski, 1989).

Others have argued in favor of earlier maturation of the right cerebral hemisphere by illustrating that due to the relative abundance of white matter in this hemisphere, early trauma within this general region may lead to a variety of disconnection syndromes related to the functioning of commissural, projection or association fibres (Rourke, 1988), while complex language functions of the left cerebral hemisphere may remain intact . The view that right hemispheric development precedes linguistic maturation is also supported by other researchers who note significantly more deficits in right hemispheric functions including poor problem solving, visual-motor skill, psychomotor and mental efficiency and behavioral disturbances among children with cranio-cerebral trauma including acceleration-deceleration injuries and shearing of white matter, intensive radiotherapy for the treatment of cancer, and other conditions that may cause general or diffuse destruction of white matter (Fletcher & Copeland, 1988; Rutter, 1982 Taylor, 1984; 1987; Taylor, Albo, Phebus, Sachs, & Bierl, 1987). Children and adults with significant head injury also demonstrate more deficits in "right hemisphere skills" than "left hemisphere skills" as basic language functions which are overlearned tasks thought to be mediated by the left hemisphere, are generally spared while visual-spatial abilities, abstract and novel thinking skills, and complex memory and learning, are often affected. In some cases, this can readily be seen in lower Performance IQ ratings relative to Verbal IQ rating on the WISC (Rutter, 1982).

These important neurodevelopmental periods are often referred to as "critical periods" and are defined as periods during which the organism is maximally sensitive to particular exogenous or external influences (Novick & Arnold, 1988). As noted above, the potential for trauma to the developing brain occurs early and likely within the first eight to ten weeks of conception. It should also be noted that the second period of brain growth (from about 20 weeks of gestation onwards) is also considered to be an important period of growth and development as developmental vulnerability is at its peak, particularly with respect to the likely origin of several developmental disorders that occur later in childhood, including Learning Disability. This gestational period is also the time when most premature infants are delivered, and thus appear to be a greater risk neurodevelopmentally, when compared to their normal birthweight counterparts.

From the moment of conception, cells begin to grow and differentiate into structures that will eventually develop into brain tissue with highly complex functions. This process continues in a developmental progression as determined by genetically-encoded information, and in the absence of trauma this process will lead to the development of "healthy" brain tissue. When this process is inadvertently interrupted by trauma such as premature birth however, brain tissue may suffer damage which may then alter the course of brain development. If this trauma is of a significant nature and occurs within the early embryonic period, developing brain tissue may be substantially altered and lead to significant deficits in brain functioning, likely affecting global cognitive skills such as mental retardation, or other developmental disorders. If the insult occurs during the second important period of brain growth and organization, more subtle deficits may arise based on the severity of the initial trauma as well as male / female differences in brain growth and maturation. In other words, the outcome of early brain injury in males or females may depend at least in part upon the stage of brain development (Strauss, Wada, & Hunter, 1992), resulting in males being at perhaps greater risk. The fact that brain maturation occurs more slowly in males than females has been well documented (Conel, 1939), and it is possible that the greater immaturity of the male brain at a critical (early) period may make it more susceptible to neonatal insult; a finding also well noted in animal research (Stewart & Kolb, 1988). More importantly, research evaluating the etiology of other more subtle disorders of mental processing, including Learning Disabilities, tends to support the idea that the developing male brain may be more vulnerable to insult (Willis & Widerstorm, 1986) as males significantly outnumber females with Learning Disabilities.

Also with respect to higher cortical functions, there appears to be added support for the hypothesis that sex-related differences in intellectual functioning following early trauma to the brain, reflects differences in rates of maturation. Kolb and Whishaw (1989), have shown that morphological changes occur in several states in the animal brain. The stages of cell proliferation and migration tend to occur in the prenatal period in humans but a considerable portion of axonal and dendritic growth including cell death occur in the postnatal period. It seems reasonable to assume therefore, that early traumatic events including infections, cerebral hemorrhages, or anoxic events that jeopardize cell growth and differentiation, dendritic or axonal growth, as well as synaptic growth, may lead to the development of an anomalous brain either in general or for specific regions, depending on the particular event and its "timing" with respect to maturational states. In addition to the increased growth and differentiation, selective death of cells, axons, dendrites and synapses, is often seen particularly in the postnatal period. The postnatal period is also considered to be very critical as it is the time of greatest synaptic formation as noted in primates (Rakic, Bourgeois, Eckenhoff, Zekevic, & Goldman-Rakic, 1986), followed by another critical period consisting of the elimination of at least 50% of synaptic contacts. It is reasonable to assume that lesions that occur during the synaptic formation period will likely be more debilitating than those that occur later during synaptic loss. It is equally likely that these subtle but gross disruptions in morphology at the cellular level may severely limit the capacity of the developing brain to support (later) complex functions such as reading, spelling and mathematics, particularly for males brains, that not only mature at a slower rate, but also appear to be more susceptible to damage at this cellular level. There is also a growing body of research identifying sex-related differences in brain growth and potential sources of insult in the fetal brain involving the interplay and action of gonadal hormones, particularly for the cortex and hippocampal regions (Strauss, Wada, & Hunter, 1992). In a similar vein, Geshwind and Behan (1982) have suggested an interaction between neuronal growth, immune development, and testosterone in the developing brain, and hypothesize that this leads to a delay in maturation of the left hemisphere leading to disruptions in the establishment of normal language functions and patterns of manual dominance.

It would appear, therefore, that the effects of brain insult appear to be more profound on the developing brain than for the mature brain. This is due to the concept of critical periods in brain development discussed previously. There are, however, at least two theoretical exceptions to this rule that relate to the concept of "plasticity" (Hynd & Willis, 1988). The first theory postulates that the younger, immature brain is less affected by hypoxia than the mature brain. The second rule states that the younger brain is less profoundly affected than the mature brain by certain forms of injury or insult as the younger brain has a greater recovery potential due to neuronal plasticity. In essence, the theory states that affected neurons may be replaced by new ones or by those selected from other areas during the time that neuronal tissue is growing and differentiating. This theory is based on observations attesting to the younger brain's pliability or plasticity as it seems to have a greater ability to recover from insult than a mature brain. However, some differences are observed between males and females. For example, early lesions or dysfunction of the left (dominant) hemisphere can be demonstrated to show more generalized cognitive retardation in males whereas intellectual deficits appear to be linked to a shift in speech processes in females. This may reflect a sex-related difference in outcome due to interruption at different maturational stages and/or the influences of gonadal hormonal systems in fetal brain growth, particularly for the cortex and hippocampal regions (Strauss, Wada, & Hunter, 1992). This relative "sparing" of language functions in females following early insult to the left cerebral hemisphere attests to the plasticity issue and is attributable to the acquisition of speech and language functions by intact regions in the left or right hemisphere (Rasmussen & Milner, 1977; Satz, Strauss, Wada, & Orsini, 1988). On the other hand, this "plasticity" comes with a heavy price particularly for males who may show a shift of language functions from the damaged left hemisphere to the "nondominant" right hemisphere (Kolb & Whishaw, 1989; Strauss, Satz, & Wada, 1990). These individuals frequently display more generalized cognitive deficits including language production, learning and memory (Strauss, Wada, & Hunter, 1992).

It seems apparent that the idea of "plasticity" is limited in the child's brain and even more limited in the immature or developing brain. The effects of an early insult due to prematurity, for example, may not be evident at the time it occurs, but the sequelae may emerge subtly later in childhood, when more advanced functions (that depend on the affected regions) are expected to emerge. This process may represent one of the central theories related to the etiology of Learning Disabilities in addition to linking this field to deficits in the higher-order cognitive processing required for most academic tasks. Many of these insults to the brain of a premature child are caused by medical complications of prematurity itself and need to be examined more closely.

Medical Complications Of Premature Birth

Many conditions associated with premature birth are known to assault the central nervous system. In turn, the central nervous system which regulates behavior and development may show varying degrees of impairment as a result of either indirect or direct insult occurring during the premature birth period. These conditions, either singly or in some combination, may effect or compromise the future physical, emotional, social, and intellectual development of the child, thereby contributing to a variety of neurodevelopmental disorders including Learning Disabilities (Commey & Fitzhardinge, 1979; Pfeiffer, Heffernan, & Pfeiffer, 1985).

From the physiologic point of view, respiratory difficulties resulting from immature lungs pose a serious threat, not only in terms of lung collapse, but also in terms of diminished oxygen transport to brain tissue. As many as 35% of all Prematures seem to be affected by this condition (Field, Dempsey, Ting, Hallock, & Shuman, 1982). Respiratory Distress Syndrome (RDS) is often associated with apnea, where immature breathing control mechanisms in the brain cause lapses in breathing of significant duration. Episodes of bradycardia, or slowed heart rate, can occur concomitantly which may further reduce oxygen flow to the brain (Fitzhardinge & Ramsay, 1973; Perlman & Volpe, 1985). The extended use of mechanical ventilation to reduce the risks of RDS can lead to damaged lung tissue and scarring. This too, reduces the aeration of the blood which in turn would effect brain tissue in the form of hypoxia. Anoxia or anoxic episodes are centrally linked to a number of serious neurodevelopmental and cognitive disorders ranging from cerebral palsy to mental retardation.

At the other end of the spectrum, Retrolental fibroplasia (RLF), a condition associated with high concentrations of oxygen applied during mechanical ventilation procedures, results in hyperoxaemia which may damage the developing retina and lead to mild, moderate, or severe forms of visual impairment, including myopia, partial visual-field loss, and blindness (Stavis & Krauss, 1980). While some researchers noted a decrease of RLF in the early 1960's as oxygen inspiration became more carefully monitored (Stewart, Reynolds, & Lipscomb, 1981), other researchers contend that it is again on the increase as younger and smaller Prematures survive, particularly those with very low birth weight (VLBW). Studies conducted on small Prematures reveal the incidence of visual difficulties may be as high as 22% to 42%, including 5% to 11% for cases of blindness alone (Henig, 1983; Moore, 1981).

Another complicating medical condition is intraventricular hemorrhage (IVH), occurring in higher proportions in infants under 1500 grams and caused in part by a highly fragile and permeable blood/brain barrier. Birth asphyxiation, extreme changes in blood pressure, and pressure on the head during labor can also lead to intraventricular hemorrhage (Landry, Fletcher, Zarling, Chapieski, Francis & Denson, 1984). IVH has profound effects on developmental outcome and is cited as an etiological factor for both subtle and profound neurodevelopmental dysfunction (Ahman, Lazzare, & Dykes, 1980; Gaiter, 1982; Krishnamoorthy, Shannon, Delong, Todres, & Davis, 1979; Papille, Munsick-Bruno, & Schaefer, 1983; Pfeiffer, Heffernan & Pfeiffer, 1985).

Physiologic jaundice or hyperbilirubinemia affects approximately 70% of all premature infants to some degree (Rossetti, 1986). Bilirubin is a potentially toxic substance which results from the breakdown of fetal red blood cells following birth. While in the mature infant this substance is converted into a harmless waste product, the immature liver of the premature infant allows bilirubin to accumulate in the bloodstream. So-called "free" bilirubin can enter the central nervous system and cause significant damage which has been linked to mental retardation, cerebral palsy, and varying levels of hearing impairment (Holmes, Reich, & Pasternak, 1984). Infection, thrombosis, thrombocytopenia, and possible periventricular hemorrhage are possible iatrogenic effects in the treatment of this condition (Stavis & Krauss, 1980).

The premature infant is also more susceptible to bacterial, viral, and fungal infections as the transfer of maternal antibodies may be reduced due to short gestation and immaturity of the infant's immune system. These infections can be transmitted to the infant either in utero or by exposure within the intensive care unit (Cloherty & Stark, 1980). The most serious of the intrauterine infections, including toxoplasmosis, rubella, cytomegalovirus, and herpes can result in such neurological impairments as mental retardation, seizure disorders, neuromuscular disease, and sensory difficulties including hearing and visual handicaps (Koops & Battaglia, 1984). Infections transmitted in the intensive care unit include sepsis and meningitis. Sepsis can predispose the infant to increased chances of developmental delay, mental retardation, and hearing impairment. Meningitis can lead to a variety of neurodevelopmental disabilities including seizure disorders, cognitive deficits, speech disorders, and perceptual-motor difficulties (McIntosh & Lauer, 1984).

Neurodevelopmental Outcome of Premature Birth

Major advances in medical care and treatment have contributed to the survival of the premature infant, born under 37 completed weeks of gestation and/or less than 2500 grams at birth. Many early researchers expressed a fear that increased survival rates, especially among very low birthweight infants, could lead to increased morbidity (Drillien, 1961). No doubt one of the most complicating factors affecting both mortality and morbidity figures to this day is the relation of gestational age at birth to future adverse neurodevelopmental outcome. Observations made by early researchers are only recently receiving increased attention as advances in the field of neonatal medicine has led to a dramatic "downward" extension in what is known as the "age of viability" or successful birth and survival for Prematures who have completed less than 25 weeks of gestation and who weigh less than 1000 grams. This has created a "new" population of Prematures of very low birthweight (VLBW), who appear to be at significantly higher risk for developing a host of neurological as well as neuropsychological deficits (Black, Brown, & Thomas, 1977; Horwood, Boyle, Torrance & Sinclair,1982; Pape, Buncic, & Fitzhardinge, 1978).

Opinion was initially divided as to whether the incidence of handicap was increasing at a rate commensurate with increased survival. Stewart, Reynolds, and Lipscomb (1981), in a survey of literature on outcome for very small premature infants (under 1000 grams), noted that the incidence of major handicapping conditions among survivors had remained less than 10% despite an increasing survival rate. Other researchers also noted a lower handicapping rate (Fitzhardinge & Ramsay, 1978; Friedman, Chipman, Segal & Cocking, 1982). Although some recent studies indicate that the overall incidence of major handicapping conditions may be decreasing, the actual incidence of specific types of handicap such as cerebral palsy (Kitchen, Ryan, Richards, McDougall, Billson, Keir, & Naylor, 1980; Atkinson, 1981) and retrolental fibroplasia (Phelps 1981) may be on the increase. Other researchers add that, in many cases, increased survival rates for the small premature infant may in fact predispose it to a host of adverse medical, neurological, and developmental sequelae. Therefore, even though mortality rates appear to have decreased by approximately 10% per decade, morbidity has not (Horwood, Boyle, Torrance, & Sinclair, 1982). As more and more of these very low birthweight infants (VLBW) survive with apparently "few" medical complications, they appear to be at significant risk for developmental difficulties including Learning Disabilities that are often only manifested when a child enters school or shortly thereafter (Hynd & Willis, 1988).

Literature Review on Learning Disabilities

Wiederholt (1974) in his historical review of the education of Learning Disabled children, points out that the roots of scientific and philosophical interest in LD is likely as old at those two disciplines themselves. Prior to the 1960's for example, few public school services were available for students with Learning Disabilities in North America. Since then however, there has been a worldwide surge of interest in the field that has been unparalleled in the history of educational services to handicapped individuals.

Although learning disorders in children and adolescents have been recognized for several decades, early scientific attempts at describing a "Learning Disability" included terms such as "minimal brain dysfunction", "perceptual handicap" and "dyslexia" referring to a collection of disorders that were later termed "Learning Disabilities", largely due to the efforts of professionals and parents wishing to obtain services for children with severe learning problems (Kirk, 1976). Having recognized the existence of learning disorders, the task of identifying those at risk as well as specific criteria for diagnosis was undertaken by early researchers who concluded that a Learning Disability was a "psychological handicap caused by a possible cerebral dysfunction and/or emotional retardation, sensory deprivation, or cultural or instructional factors" and described it as a "retardation, disorder, or delayed development" in speech, language, reading, writing, arithmetic, or other "school subjects" (Kirk & Bateman, 1962, p. 73). At the time, clinicians and researchers viewed LD as a single all inclusive disorder or "psychological handicap" and included all children with significant delays in academic achievement regardless of the etiology of the handicap. It soon became evident that LD was a complex disorder that required more rigid inclusion and exclusion criteria. Other definitions arose which included such factors as uneven patterns of psychological development or "developmental imbalances", including the need for special education programming for "deviant developmental processes", as well as criteria for academic deficiency such as being "four years or more" behind their peers (Gallagher, 1966, p. 28).

The most prominent feature of these early definitions was the attention given to the discrepancy between the child's estimated intellectual ability, or potential for learning and the actual level of academic achievement. Bateman (1964), recognizing the need for exclusionary criteria, concluded that a Learning Disability could be diagnosed in children who:

> "manifest an educationally significant discrepancy between their estimated intellectual potential and actual level of performance related to basic disorders in the learning processes, which may or may not be accompanied by demonstrable central nervous system dysfunction, and which are not secondary to generalized mental retardation, educational or cultural deprivation, severe emotional disturbance, or sensory loss." (p. 220)

While these definitions recognized that neurological dysfunctions were present in some LD children, their presence or the ability to demonstrate this dysfunction, was not considered to be crucial to the diagnosis. The actual cause or etiology of LD was not addressed by these definitions until Johnson and Myklebust (1967) made explicit references to the central role of neuropsychological dysfunctions by describing these children as having a "psychoneurological Learning Disability" being due to "a dysfunction of the brain" resulting in "altered processes" as opposed to "a generalized incapacity to learn" (p. 8). These authors also underscored the importance of uneven patterns of skills as the central feature of LD, suggesting that some neurologically related abilities were affected while other were spared.

With further revisions of the definition, it soon became apparent that LD diagnosis was more or less restricted to a learning handicap that was not caused by generalized intellectual retardation or peripheral or environmental factors, but related more to uneven patterns of development including documented or inferred neurological dysfunction. It was also recognized at that time that a wide array of specific learning disorders were diagnoseable based on the pattern of academic difficulties that the child displayed. These early definitions also established the central role of neuropsychological dysfunction as the etiology of LD even though the exact nature or cause of such dysfunctions was generally not known or subject to considerable inter-individual variability. This is consistent with many recent definitions of LD except that central nervous system dysfunction can now be clearly demonstrated both in post-mortem studies and "in vivo" via sophisticated diagnostic imaging techniques (Hynd, Marshall, & Gonzalez, 1991; Gaddes, 1985; Galaburda & Eidelberg, 1982; Galaburda & Kemper, 1979, Galaburda, Sherman, Rosen, Aboitiz, & Geshwind, 1985).

The National Joint Committee on learning Disabilities (NJCLD), comprised of representatives from a variety of professional organizations and associations, in response to the need for a comprehensive and current definition of LD, proposed the following definition in 1981:

> "Learning disability" is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and presumed to be due to Central Nervous System Dysfunction. Even though a Learning Disability may occur concomitantly with other handicapping conditions (eg., sensory impairment, mental retardation, social and emotional disturbance) or environmental influences (eg., culture differences, insufficient/inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences." (Hammill, Leigh, McNutt, & Larsen, 1981)

The importance of recognizing LD as a heterogeneous group of disorders involving central nervous system dysfunction as well as the exclusion of criteria that restricted the definition to children in order to incorporate adults, is underscored by this current and well accepted description. This definition also recognizes the neurological basis for the problem as well as the potential for Learning Disabilities to occur within varying handicapping conditions and in different cultural and linguistic groups, but not being caused by these factors. A number of other recent definitions of LD have been proposed with subtle changes noted, however, most include at least four basic dimensions. The first characteristic shared by all recent definitions of LD is the apparent discrepancy between the expected and actual performance on an individual. Although not all definitions explicitly include the discrepancy criterion, it is generally accepted and implied in clinical practice. The second basic similarity is the existence of behavioral manifestations or indicators of strengths and weaknesses in learning in academic and language areas for LD children. The third dimension relates to the general integrity of the condition where LD is differentiated from other handicapping conditions. The fourth dimension of similarity between definitions of LD includes a focus on the primary explanation of the learning problem. Different definitions of LD have arisen as a result of various shifts in philosophy which have focused attention on developmental problems, neurological dysfunctions, psychological processes, language problems, and task / environmental factors.

Subtypes of Learning Disability

Research on LD has gone through, and continues to go through, considerable change and evolution (Gaddes,1980; Hynd & Obrzut,1981a; Rourke,1985; 1991a), and currently enjoys remarkable exposure both with respect to research on children as well as adults (Goldstein, Katz, Slomka, & Kelly, 1993; Mattis, French, & Rapin, 1975; McCue, Shelly, Goldstein, & Katz, 1984; McCue, Shelly, Goldstein, & Katz,1986; Spreen, 1987; Spreen & Haaf, 1986). The heterogeneous nature of LD has also been clearly recognized in addition to multiple factors or causes related to the etiology of this disorder. This heterogeneity implies the existence of certain subtypes of LD and researchers have noted the existence of several subgroups, particularly in the areas of reading disabilities (Boder,1970; Mattis, French & Rapin,1975; Pirozzolo,1979; Pirozzolo & Rayner,1979; Rourke,1985; Rourke, Bakker, Fisk & Strang, 1983), although spelling (Naidoo,1972; Nelson & Warrington,1974; Sweeney & Rourke,1978), and arithmetic disability (Rourke, 1985; 1991a; Rourke & Strang,1978; Rourke & Finlayson,1978) subtypes are also noted, including the nonverbal Learning Disability subtype with its unique pattern of deficits (Myklebust, 1975; Rourke, 1982;1987; 1988b; 1989; 1991a; Rourke & Finlayson, 1978; Rourke & Strang, 1978 ; Rourke, Young, Strang, & Russell, (1986).

Researchers have traditionally used a number of approaches in their attempts at subgrouping based on clinical diagnostic classifications (Boder, 1973; Johnson & Myklebust, 1967; Mattis, French & Rappin, 1975), classification according to patterns of academic underachievement or neuropsychological dysfunction (Fisk & Rourke, 1979; Hynd & Willis, 1988; Morris, Blashfield, & Satz, 1981; Rourke, 1985; 1991a; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983), and statistical approaches relying on computer generated subgroupings using factor analysis and a priori grouping (Petrauskas & Rourke, 1979, Rourke, 1985; 1991a) or cluster analytic techniques (Batchelor & Dean, 1993;Doehring, Hoshko, & Byrons 1979, Rourke, 1985; Spreen & Haaf, 1986).

Reading Disabilities (Dyslexia)

Practical classification systems for diagnostic or clinical purposes often rely on patterns of academic achievement to identify LD subtypes. This approach was inspired earlier by Johnson and Myklebust (1967) who identified basic auditory and visual patterns of reading disability, as well as other patterns including "inner-language dyslexia" described as a deficiency of "integrative-neurosensory learning" and characterized by normal phoneme-grapheme encoding but poor comprehension; "auditory dyslexia" pertaining to "cognitive auditorizing", symbolizing and coding written language in the absence of impairment in spoken language comprehension; "visual dyslexics" who displayed visual-verbal agnosia; and "intermodal or cross-modal dyslexia" in individuals who have difficulty translating visual processes into auditory processes despite having intact "intraneurosensory auditory and visual processes". These early attempts at classification were very creative but were criticized due to a failure in demonstrating the existence of clear and distinct subtypes in research. However, this early research was able to consistently demonstrate the existence of at least two types of reading disabilities with primarily verbal or visual-spatial deficits, based on presumed dysfunction of the left and right cerebral hemispheres, respectively. These early attempts also identified the potential patterns or variations in subskills that underlie the learning process in a manner that was very conducive to future research.

One of the researchers influenced by these early attempts was Boder (1973) who sought to classify reading disabled children based on the qualitative nature of their reading-spelling patterns. Based on clinical observations, Boder (1973) divided reading disabled children into three groups: 1) Dysphonetic dyslexics who have auditory-linguistic deficits that lie at the root of their inability to process or analyze phonemes and display poor sound-symbol understanding (approximately 67 percent of her sample), but appear to have relatively intact visual-spatial skills, 2) Dyseidetic dyslexics who display deficits in visual-spatial analysis or fail to perceive words as gestalts (approximately 10 percent of her sample), but who show intact auditory-linguistic functions, and 3) Mixed dysphonetic/dyseidetic dyslexics who display deficiencies in both auditory-linguistic and visual-spatial ability related to the reading process. Boder's classification system assumed that dysphonetic dyslexics appeared to have deficits in the left cerebral hemisphere, dyseidetic dyslexics had deficits in the right hemisphere, and mixed dyslexics had deficits in both cerebral hemispheres. Studies evidencing electroencephalographic asymmetries in normal and dyslexic readers have been noted (Fried, 1979; Fried, Tanguay, Boder, Doubleday, & Greensite, 1981), as well as studies indicating perceptual asymmetries in the processing of verbal and nonverbal information (Pirozzolo & Rayner, 1979; Dalby & Gibson, 1981), appear in support of Boder's classification system.

Six distinct reading disability subtypes were also described by Denckla (1977,1979), based upon clinical observation, including : 1) a global-mixed language disorder subtype, 2) an articulation-graphomotor disorder with poor articulation and fine-motor dexterity, 3) an anomic-repetition disorder identified by poor naming (semantic substitutions) and deficient digit and sentence repetition, 4) a dysphonetic sequencing disorder indicated by poor digit and sentence recall and naming but with phonemic substitution or reversal errors in reading, 5) a verbal learning and memorization disorder, and 6) a correlational disorder with relatively normal reading skills but at a significantly lower level than measured intelligence.

Another group of researchers sought to apply a clinical approach to the analysis of neuropsychological test results on three groups of children including : Children with known brain damage but no apparent reading problems, children with brain damage and dyslexia, and children with dyslexia but no evidence of structural brain damage. In researching these groups of children, Mattis, French and Rapin (1975) found no significant whole group differences between the two dyslexic groups, however, three identifiable subgroups emerged within both dyslexic groups. Approximately 38 percent of their dyslexic sample evidenced a pattern of generalized language disability, including deficits in naming, listening comprehension, sentence repetition, and speech sound discrimination. The second group comprising 37 percent of the sample of dyslexics, displayed significant motor-speech difficulties (articulation-graphomotor dyscoordination), including deficits in sound blending and graphomotor ability. A third group was also identified, making up about 16 percent of the sample of dyslexics who evidenced visuospatial perceptual impairment with deficiencies on various visual or nonverbal tasks including the WISC Performance IQ, Raven's Progressive Matricies, and the Benton Visual Retention Test.

One of these researchers (Mattis, 1978), went on to conduct a cross-validation study with a larger sample of reading disabled children and found essentially similar results except that 63 percent of this second sample was classified as having a language disorder, 10 percent as having articulation-graphomotor dyscoordination deficits, 10 percent classified as having a temporal sequencing disorder, 5 percent evidencing visual perceptual disturbance, and 9 percent showing mixed disorders with features of two or more of the classification types. These neuropsychologically based studies presented results generally consistent with Boder's earlier finding of a larger auditory-linguistic subgroup (although divided into three distinct subtypes), and a relatively small visual-perceptual disorder subgroup of reading disabled children.

Bakker (1973, 1979, 1982, 1983), provides yet another example of a clinically based diagnostic classification system of reading disability subtypes based on lateralized brain deficiencies. Bakker proposed that reading skills develop in stages based on developmental shifts that involve each cerebral hemisphere from the early stages of perceptual analysis of unfamiliar script processed by the right hemisphere, to more advanced syntactic-semantic analysis of written material processed by the left hemisphere. According to Bakker, processing deficiencies of either hemisphere could give rise to different patterns of reading deficit such as an over-reliance on left hemispheric linguistic strategies for those with right hemisphere dysfunction (L-type dyslexics), who manifest a relatively fast reading rate but who make numerous errors of omission, substitution or addition, based on an inability to recognize the visual-spatial features of the text. Children displaying the opposite pattern (P-type dyslexics) have intact right hemispheric functioning but deficient verbal-linguistic ability tend to ignore the symbolic representation nature of words and would therefore show a slower reading rate or evidence errors of fragmentation and repetition, according to Bakker. Evidence for these subgroups is also cited in dichotic stimulation studies showing differential patterns of lateralization of language functions with P-type dyslexics displaying a higher than normal incidence of right hemispheric dominance for language/speech function by showing a left ear advantage on verbal dichotic listening tests (Bakker, Licht, Kok, & Bouma, 1980).

Another popular approach to subgrouping using neuropsychological data involves the use of a priori groupings (Fisk & Rourke, 1979; Morris, Blashfield, & Satz, 1981; Petrauskas & Rourke, 1979). In this approach, Learning Disabled children are subtyped a priori on the basis of their pattern of performance on academic achievement tests in an attempt to determine if the differential academic problems are related to different patterns of neuropsychological impairment. In an early attempt Rourke and Finlayson (1978) succeeded in classifying LD children based on the results of the Wide Range Achievement Test (WRAT; Jastak & Jastak, 1965) for reading, spelling and arithmetic achievement, into three a priori groups: Children in Group 1 evidenced uniformly deficient performance on all three measures; Group 2 children showed average or better performance in arithmetic but weaknesses in reading and spelling; while Group 3 children showed average or better ability in reading and spelling but relatively deficient arithmetic performance. The performance of these three groups was then contrasted on a series of 16 measures of intellectual and neuropsychological ability resulting in the significant finding that Group 1 (deficient overall) and Group 2 (low reading and spelling but good math), were superior to Group 3 (low math but good reading and spelling), on measures of visual-spatial and visual-perceptual ability, while Group 3 was superior to Groups 1 and 2 on measures of verbal and auditory-perceptual ability. The authors proposed that based on the pattern of neuropsychological test performance, Group 3 children (low math but good reading and spelling) likely displayed deficits in the right cerebral hemisphere, while Group 1 (deficient overall) and Group 2 (low reading and spelling but good math) illustrated signs of left hemisphere dysfunction. This hypothesis of differing patterns of cerebral dysfunction related to different patterns of Learning Disability, has found considerable support in a number of studies viewing lateralized motor deficits in older LD children (Rourke & Strang, 1978; Rourke, Yanni, MacDonald,& Young, 1973), and on tasks involving sequential analysis and visual scanning (Rourke & Finlayson, 1975).

Spelling Disabilities (Spelling Dyspraxia)

Spelling disability subtypes have often been identified in relation to reading patterns as they tend to share considerable similarity as discussed in the above research findings. Until recently, knowledge pertaining to the processing skills necessary to for spelling or responsible for a specific dysfunction in spelling has been lacking. Early studies of spelling dysfunction (Bannatyne & Wichiarojote, 1969; Newton, 1961; Russell, 1955), failed to find consistent or replicable results and were frequently ambiguous or contradictory since a "level of performance" approach was used which did not take into account the many subskills that are required and the fact that these subskills may vary with different stages of development of spelling skills. Recognizing that these variables exist and that there may be qualitatively different deficits in processing capabilities of spelling disabled children, researchers began isolating these strategies by classifying errors from a psycholinguistic point of view. These early studies noted a preponderance of phonetically inaccurate errors and significant Verbal<Performance IQ discrepancies on the WISC (Nelson & Warrington, 1974), or more generalized impairment of language functioning that continue into adulthood (Kinsbourne & Warrington, 1964; Newcombe, 1969). Sweeney and Rourke (1978), in addition to others (Naidoo,1972; Nelson & Warrington,1974) have identified distinct patterns of spelling disability (spelling dyspraxia) from a neuropsychological perspective that are particularly useful for classification purposes.

On the basis of academic underachievement on the WRAT, Sweeney and Rourke (1978) defined spelling "retardation" as centile score of 20 or below on the Spelling portion of the WRAT. This group was further divided into those who were phonetically inaccurate (PI) or accurate (PA) spellers, based on their error pattern, and their performance on a variety of neuropsycholgical measures taken at different age levels, was compared to normal spellers with centile scores in the 50 or above range (WRAT). The results suggested that the differences in spelling were not due to problems in selective attention as both PI and PA spellers did not differ on tests of selective attention and discrimination when compared to normals. In addition, differences between PA, PI, or Normals, were not found on tests of visual closure or Performance IQ., suggesting that language-related "visualizational skills" or perceptually-related intellectual dysfunction alone was not responsible for spelling deficits. Differences were found among the three groups for older children as children with phonetically inaccurate spelling errors (PI) performed much poorer than older normals on tests of auditory-verbal receptive skills, suggesting a basic deficiency in these psycholinguistic subskills for children with specific spelling disability. This finding would tend to explain why the most deficient spellers also showed global language deficits including verbal intellectual ability (Nelson & Warrington, 1974), that could also be detected as dysphasia in adulthood (Newcombe, 1969; Kinsbourne & Warrington, 1964).

It would appear that the children exhibiting phonetically inaccurate misspelling have a significant deficiency in carrying out basic, receptive linguistic operations and therefore would have similar difficulty performing phonemic operations, including the phonemic segmentation required for spelling. Problems in phonemic analysis and synthesis were also noted by Luria (1980) who described adult patients with lesions of the secondary zone of the left temporal lobe. On the other hand, the psycholinguistic deficit of phonetically accurate misspellings seemed much less debilitating as they did not show the magnitude of linguistic deficits that the PI groups evidenced. In fact, the phonetically accurate misspellers (PA) performed at a level similar to normals for the older age group on the more simple psycholinguistic tasks used in the study. Sweeny and Rourke (1978) however, noted some deficits in complex psycholinguistic functions for this group on tests that required encoding of relatively complex word strings or the ability to cognitive extrapolate beyond the verbal information given. The researchers further speculated that PA's may have difficulty in associating the spoken word with visual-spatial information. This lack of awareness or appreciation for the visual-spatial features of a word (ie., what the word "looks like"), may be the result of a "rigid adherence to the sound-symbol associational system" (p.155), and may serve to highlight the importance of visualization skills in the encoding or decoding of word strings for relatively complex language functions to occur. This patterns of deficits was also noted by Luria (1980) who suggested that lesions of the left hemisphere (parietal-temporal-occipital area) tertiary zone, may be responsible, as patients would manifest difficulty selecting appropriate graphemes to represent the spoken word even though they could comprehend the word quite well.

In longitudinal study (4 years) testing the stability of the hypothesis that phonetically inaccurate spelling was a good indicator of serious reading deficit, Burgher and Rourke (1976) evaluated the performance of younger children (Grades 2, 4, 5 & 6) with phonetically inaccurate (PI) and phonetically accurate (PA) misspellings with that of normal controls (N) in a similar fashion to the study discussed above and found essentially similar results (PIs<PAs<N). In other words, children in the PI group were persistently found to display significantly more reading problems than the PA children or the controls. It was suggested that the impact of phonetic inaccuracy on reading disability was progressively more serious over the developmental sequences investigated, indicating that the apparent deficiency in certain receptive linguistic skills such as phonemic synthesis and segmentation, represents a deficit that does not correct itself with age (Rourke, 1976). The results of several other more recent unpublished studies also appear to confirm this general finding (Sweeney & Rourke, 1985).

Arithmetic Disabilities (Dyscalculia)

Learning disabilities have been traditionally defined as reading and/or spelling deficits largely due to a focus on these areas from both a research perspective and academic remediation. This interest was also due to the relatively early and dramatic manifestation of these patterns of difficulty among children when compared to arithmetic difficulties which are frequently identified much later in a child's academic career. This may have contributed to the common notion that genuine disabilities in arithmetic did not exist or existed in addition to reading and spelling difficulties or due to more global underachievement. In fact, arithmetic disabilities were not clearly recognized until Goodstein and Kahn (1974) demonstrated their existence independent of reading and spelling difficulties. With these observations in mind, Rourke and his colleagues successfully identified children with specific arithmetic disabilities based on their performance on the WRAT (Rourke & Finlayson, 1978; Rourke & Strang, 1978; Rourke, 1985; Strang & Rourke, 1983, 1985).

Unlike reading, mechanical arithmetic is a complex academic subject as even simple problems require stepwise application of rules and procedures that frequently result in an error due to small mistakes that can be made at any point in the calculations. In reading however, one can omit or skip significant portions of the material and still be able to comprehend a good portion of the material. This relationship has been well documented by Strang and Rourke (1985), who noted that young reading disabled children with average or better arithmetic ability, tended to perform better in comprehension tasks than in decoding tasks. While it can be argued that deficits in arithmetic skills can also be due to poor instruction, immaturity, inexperience or insufficiencies with the teaching curriculum, poor motivation, anxiety or even emotional disturbance (Slade & Russell, 1971), others have argued that these factors alone do not account for the patterns of arithmetic disability frequently encountered in children. In fact, researchers have demonstrated that due to the complex nature of learning and using arithmetic skills, a wide variety of neuropsychological impairments are likely to be involved ranging from verbal memory deficits (Rourke & Finlayson, 1978; Tuoko, 1982), to more cognitive and brain-related disorders of right hemispheric dysfunction (Batchelor & Dean, 1993; Rourke & Finlayson, 1978;Strang & Rourke, 1978, 1983,1985), that continued well beyond childhood and into adulthood following essentially similar patterns of dysfunction (Goldstein, Katz, Slomka, & Kelly, 1993; Rourke, Young, Strang, & Russell, 1985; Spreen, 1987; White, Moffitt, & Silva, 1992).

Rourke and his colleagues have completed three neuropsychological studies with children who illustrate the pattern of specific arithmetic disability. In the first two studies (Rourke & Finlayson, 1978; Rourke and Strang, 1978), also discussed earlier with respect to reading disability patterns, three groups of children were selected on the basis of their performance on the WRAT Reading, Spelling and Arithmetic subtests. Children in Group 1 were uniformly deficient on all three subtests (all 2 grade levels below their peers on all subtests), while children in Group 2 were relatively skilled in arithmetic (although they were below average on age-norms), but poor in reading and spelling (at least 1.8 grades below the Arithmetic scores), and Group 3 children were poor in arithmetic but at average or above levels in reading and spelling (grade scores in these areas were 2 years above the math score). All children were right-handed and had Full Scale (WISC) IQs within the 86-114 range (N = 15, ages =

9 - 14). They were administered a series of tests designed to measure auditory-perceptual, verbal, and visual-perceptual skills (Rourke & Finlayson, 1978) as well as motor, psychomotor, and tactile-perceptual ability (Rourke & Strang, 1978). None of the children were reported to have sensory-motor handicaps, emotional disorder, or "cultural" deprivation including lack of schooling.

The results of the first study (Rourke & Finlayson, 1978) illustrated that Group 2 and Group 3 children had contrasting patterns of academic achievement as both were equally impaired on the Arithmetic subtest of the WRAT, but were vastly different on the Reading and Spelling subtests. Group 3 children with poor arithmetic but adequate reading and spelling patterns had well developed auditory-perceptual and verbal skills and somewhat deficient visual-spatial-organizational skills. Children in Group 2 on the other hand, who were relatively adept at arithmetic but poor in reading and spelling, scored well on tests of visual-perceptual-organizational skills but poorly on measures of verbal and auditory-perceptual skills including word blending, sound-symbol matching (Speech-Sounds Perception Test, Reitan & Davidson, 1974) and sentence memory (Rourke & Finlayson, 1978). In the second study (Rourke & Strang, 1978), it was found that Group 2 and Group 3 children also performed differently on measures of complex psychomotor and tactile-perceptual ability. It was further noted that Group 2 children (with better developed arithmetic than reading and spelling skills), performed within the average range on tests of psychomotor ability but exhibited impairments with their (dominant)right versus left hand performance on tests of complex tactual-motor learning and memory (Tactual Performance Test, Reitan & Davidson, 1974). Children in Group 3 with specific deficiencies in arithmetic on the WRAT, illustrated bilateral impairment on two measures of psychomotor ability (Grooved Pegboard Test and Maze Test; Klove, 1963). Furthermore, performance on the TPT for Group 3 children appeared to be the opposite of Group 2 ; normal (dominant) right hand performance and impaired left-hand on single trials of the TPT, with very poor performance also noted on the bilateral trial. Group 3 children also exhibited bilateral impairment on a composite measure of tactile-perceptual ability; more marked on the left side of the body. In fact, it was shown that Group 2 children appeared to perform significantly better on this task with the left (nondominant) hand.

In the third study evaluating the specific nature of arithmetic disabilities among older (ages 9-14) children (Strang & Rourke, 1983), only Group 2 and 3 (identified in a similar manner to the earlier two studies) were compared with the older children's version of the Halstead Category Test (Reitan & Davidson, 1974). The results of this study showed that Group 3 (deficient Arithmetic scores), made significantly more errors on this test of abstract reasoning and problem solving , compared to Group 2 (deficient reading and spelling), and made more significant errors on those subtests that required a higher degree of complex visual-spatial analysis. In addition, it was noted that while the performance of Group 2 was age-appropriate, the performance of Group 3 children was approximately one standard deviation below the mean for that age. The conclusions drawn from these studies (Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983), suggest that deficits in skills served by the left cerebral hemisphere are likely to exist among Learning Disabled children who display poor performance on the WRAT Reading and Spelling subtests in relation to their (better) performance on the Arithmetic subtest (Group 2). These children also tend to perform better on tests thought to tap the functions of the right cerebral hemisphere. In contrast, the opposite pattern appears to be present for Learning Disabled children who display good performance on the WRAT Reading and Spelling subtests but poor performance on the Arithmetic subtest (Group 3). These children tended to display more deficits in right hemispheric functions while showing relative strengths in those skills often associated with left-hemispheric functioning (Strang & Rourke, 1985).

Research on Developmental Outcome for Prematures

As discussed earlier, Learning Disabilities are the most commonly diagnosed disorder of childhood. Some researchers have described this condition as afflicting a greater number of children than the combined population of children with seizure disorders, cerebral palsy, or severe mental handicap (Duane,1979). As a result, this field has historically received little research interest or funding, compared to other more prominent developmental disorders including mental retardation. Funded research and greater awareness of LD among practicing clinicians has resulted in a number of recent breakthroughs including the identification of children with subtle neurodevelopmental dysfunction (Myklebust & Boshes, 1969; Hynd, Connor, & Nieves, 1988; Hynd, Marshall, & Gonzalez, 1991) and with relatively enduring patterns of deficient academic performance (Trites & Fiedorowicz, 1976) that can be traced well into adulthood (Goldstein, Katz, Slomka & Kelly, 1993; Rourke, Young, Strang & Russell, 1986; Spreen, 1987). In many cases, the effects of a Learning Disability have also been shown to extend well beyond scholastic underachievement to include self-concept (Bloom, 1976) behavioral disturbances and psychopathology (Rourke, 1988a; Rourke & Fisk, 1981; Watt, 1987).

Researchers are beginning to understand the underlying neuropsychological factors contributing to this condition, This explosion of knowledge gained from diverse fields, including education, psychology, pediatrics, neurology, audiology, and speech-language pathology, has produced a growing body of evidence linking early developmental insults to the etiology of LD. Early researchers in their efforts to identify simple precursors of academic difficulty have largely abandoned their efforts in favor or more multi-modal research paradigms including biological models to identify children at risk for school failure. These researchers have proposed that Learning Disabilities are likely attributable to insult during the pregnancy or the neonatal period (Koop & Krakow, 1983; Quinn, Sostek & Davitt, 1979), where subtle learning problems are seen as the mildest expression of insult on a continuum that includes minor sensory and intellectual handicaps at one extreme and death or severely handicapping conditions at the other (Pasamanick & Knoblock, 1961).

Developmental Models of Premature Birth Outcome

Most of the research concerning developmental outcome of Prematures has been conducted using a variety of theoretical models to account for the long-term outcome associated with premature birth. This variety helps to underscore and reflect the diversity of disciplines that share an interest in low birthweight children. An analysis of the major theoretical paradigms should therefore provide an appropriate perspective in which to gauge the relevance of the current research project.

Much of the thrust of both the early and current medical research has focussed on the impact of biological trauma during pregnancy and the perinatal period on subsequent development. This research operates from the "biological model" in the adoption of a linear or main effect manner where researchers assume that it is possible to specify particular events during the pregnancy or delivery that predict long-term consequences, regardless of intervening experience (Gisell & Amatruda, 1941). The concept of adverse events was later stated in terms of a continuum of causality resulting in various degrees of brain damage. The link with more subtle forms of brain damage, resulting in a variety of observed learning deficits, was established early in the 1960's, labelled as "minimal brain damage" by the early 1970's, and finally presented as "Learning Disability" in the late 1970's to the current year.

There is little doubt that the biological model greatly influenced early research as it gave rise to large scale follow-up studies of the 1950's and 1960's, both in Britain and the United States. As noted above, these classic studies reported the incidence of major and minor handicapping conditions among Prematures and clearly established low birthweight as a biological risk factor. Attempts were then made to refine the nature of the biological risk by examining infant factors such as precise birthweight and degree of prematurity, illness factors such as anoxia or respiratory difficulties, and treatment effects such as amount of oxygen and feeding practices. Outcome measures were also refined to include more subtle areas of damage associated with school failure in the absence of major and minor physical handicaps. The biological model's final and continuing theoretical contribution to research among

Prematures is the search for infant predictors of later functioning in a variety of areas.

The second major approach that evolved from researching Prematures incorporates an additive model which reflects the relationship between birth condition and childhood functioning as influenced by intervening variables such as family background or socio-economic status (SES), on premature birth outcome. Although the link between SES and school achievement had been known since the 1940's, it was not until the 1960's that strong evidence argued for the effect of SES on low birthweight children (Benton, 1940). This research went on to identify social condition and premature birth as two important factors predictive of later outcome (Knoblock & Pasamanick, 1966). Furthermore, the findings of major outcome studies of the period suggested that SES and low birthweight acted in an additive fashion to influence outcome, with Prematures at all levels of SES showing various deficiencies in performance relative to controls (Douglas, 1960; Wiener, 1968).

The results of these and other studies also indicated some apparent incongruities in that, on re-evaluation and subsequent re-interpretation, poor child rearing practices rather than low birthweight per se, significantly influenced outcome (Douglas, 1960). In some cases (Drillien, 1967), it was also observed that low birthweight children from high SES backgrounds did not show any serious deficits by school age. This led some researchers to propose a third and more interactional model, rather than an additive model, to help explain the influence of low birthweight and SES on outcome. The overall importance of background variables such as SES rather than birth factors led some researchers to redefine this transitional model. They held that enduring characteristics of the environment are more important than any single critical incident such as low birthweight in determining later outcome (Sameroff & Chandler, 1975). This model predicted that exposure to a high SES environment would remove the effects of low birthweight by school age, or that the ameliorating effects of high SES should become increasingly apparent in low birthweight children.

These models reflected the increasing awareness of the role of ongoing environmental factors to outcome and resulted in a shift in thinking from simple to multiple predictors of childhood development. Recent research tends to support the view that low birthweight children perform less well than their full-term counterparts. However, there appears to be less agreement as to whether this can be ascribed to biological vs. environmental factors. Predicting developmental outcome then, becomes a formidable task as there appear to be a number of significant variables that may interact in negative ways to effect future outcome. What follows is a brief discussion of both early and recent research which exemplifies these theoretical positions.

Predicting Developmental Outcome for Prematures

A number of early studies looked at predicting outcome from assessments conducted during the neonatal period. Among these studies, Drage and Kennedy (1966) tried to illustrate the important predictive validity of the Apgar scoring system. This scoring system assesses heart rate, breathing effort, muscle tone, reflex irritability, and color of the infant on a ten-point scale, conducted 1 and 5 minutes after birth. Healthy full-term infants usually have Apgar scores of 8 to 10 while preterm scores often fall within the 5 to 7 range. Scores of 4 or lower usually indicate severe distress and are associated with poorer developmental outcome. More recent investigations attest to this system's predictive sensitivity to specific neurological handicaps such as cerebral palsy (Nelson & Ellenberg, 1981) and general neurodevelopmental disabilities (Paneth & Fox, 1983).

Other early studies noted that more than one-third of very low birthweight infants had I.Q.'s below 89, 48% fell below the 10th percentile for height and weight, 20% had neurological deficits including spastic diplegia, approximately 60% had abnormal EEG's, and only 13% were considered "normal". This early research identified the smallest Prematures (small for gestational age or SGA), as being at highest risk, primarily as a result of advances in medical technology which permitted these infants to survive. Today, with even more advances in medical technology, the age of viability or survival appears to be continually shifting to lower gestational ages, thereby increasing the general population of high risk infants. It is also conceivable, therefore, that many of these children will develop neurodevelopmental difficulties.

Conversely, Cohen, Sigman, Parmalee and Beckwith (1982), in their 5 year follow-up study, contend that many preterm infants not only survive but also perform well within the average range on many outcome measures, although they note that great variability is observed within this range. They state that most developmental outcomes are not related to hazardous events in the neonatal period, but that it would be incorrect to state that illness made no difference. In their study, most postnatal complications did not predict outcome, but all of the infants who performed poorly at age 5 on outcome measures had medical complications. They concluded that, although these early medical complications did place children at risk, the future outcome was not completely determined by them. The strongest predictors for outcome were, in fact, social factors pertaining to the environment, most notably positive and supportive infant-caregiver interaction. They concluded that social and environmental factors may amplify or attenuate problems that preterm infants have and therefore these factors would likely make the best targets for intervention (Sameroff & Chandler, 1975; Sigman & Parmalee, 1979; Sigman, Cohen, Beckwith & Parmalee, 1981).

Some researchers contend that infant head size is an important predictor of future outcome, citing no differences in cognitive or motor development in full-term and preterm infants of normal head size but finding a greater incidence of neurological impairments with marked and continuing delays for microcephalics in both groups (Feckerman, Strum & Gross, 1984). Other researchers cite heart monitoring (Fox & Porges, 1985) and polygraphic recordings (Karch, Rohmer & Lemburg, 1984) as important predictors of developmental outcome. Dubowitz and Dubowitz (1984) argue that more recent ultrasound, imaging, or detached neurological procedures may be adequate predictors of normal and abnormal neurological development when aggregated. It is also conceivable that more recent advances in imaging techniques may eventually prove very useful in future prediction research.

From a medical perspective the nature of a particular illness, rather than gestational age or birthweight alone, can be a significant factor in outcome. Meisels, Plunkett, Roloff, Pasick and Stiefel (1986) indicate that Respiratory Distress Syndrome (RDS) did not account for the significant differences noted between preterm and term infants at 2 years of age in the areas of growth and cognitive and language delays. Frequent complications from respiratory difficulties however, appeared to account for more of the variation in developmental outcome than did either gestational age or birthweight.

More recent studies appear to have both refined their sampling techniques and developed a clearer research focus. Such studies have surpassed simple comparisons of birthweight, I.Q., socio-economic status, and medical complications. Researchers such as Astbury, Orgill, Bajuk and Yu (1986) examined Average for Gestational Age (AGA) Prematures and found that if growth failure occurred (defined as placing at less than the 10th percentile by age 2), such infants had a higher incidence of major developmental disabilities, including lower psycho-motor performance, an increased rate of hypotonia, and poorer muscle development. Kitchen et al (1982) noted an improved survival rate and a decreasing rate of visual defects and severe sensorineural deafness. An increased rate of cerebral palsy was noted, however, indicating perhaps that this handicapping condition may be inversely related to lower birthweight survival (Stanley & Atkinson, 1981; Rantakallia & Van Wendt, 1985; Lipper & Auld, 1985).

The Impact of Prematurity on Development, Cognition and Learning

There have been a number of long-term outcome studies that have evaluated the cognitive, developmental, and academic functioning of low birthweight children. These studies have generally included the administration of standardized achievement tests or teacher ratings. As many of the earlier studies have been well summarized by Wiener (1962) and Caputo and Mandell (1970), only a few selected studies will be discussed below.

Early studies tended to focus on I.Q., birthweight, socio-economic status, and, to some degree, academic achievement and were primarily descriptive in nature. Benton's classic study (1940) found that socio-economic status correlated better with I.Q. than did birthweight. In a large retrospective study conducted in Sweden, Alm (1953) noted that Prematures of 2500 grams or less were over-represented in special classes at double the rate found for full-term infants. Prematures were also found in institutions at approximately 4 times the normal rate. Twice as many received government disability pensions. Prematures as adults were more likely to be declared unfit for military service, likely due to height restrictions. A higher mortality rated was also noted within this population. It is significant, however, that there were no differences between Prematures and full-terms for psychological difficulties. Hess, Mohr and Bartelme (1934) indicated that of those Prematures that had survived, 90% were in school grades appropriate for their age, implying that no ill effects were noted.

In an extensive British study of children with birthweights less than 2000 grams, Douglas (1956) found significant intellectual impairment and academic problems in a group of 400 Prematures at 8 years of age as they scored significantly lower than matched controls on standardized tests of intellectual and academic achievement. This deficit was also apparent at age 11 (Douglas, 1960) as well as at age 18 (Douglass & Gear, 1976) where there appeared to be small, but non-statistically significant differences in favor of controls on academic tests. This finding challenged the previously held beliefs that premature children "catch up" with their age peers. Douglas also noted that Prematures of high socio-economic status were relatively less impaired than low socio-economic status infants, implying a interactive effect between social class and birthweight in favour of the advantaged child. In addition, he noted that children born of uncomplicated pregnancies demonstrated less intellectual impairment than those whose prenatal environment had been compromised. Douglas also noted that the smallest Prematures had greater I.Q. decrements, a finding corroborated by many other studies (Caputo & Mandell, 1970; Churchill, 1965; Drillien, 1961 and 1964; Harper & Wiener, 1965).

The well-known Baltimore studies (Wiener, Rider, Oppel, Fischer, & Harper, 1965; Wiener, 1968, Wiener, Rider, Oppel & Harper, 1968) attempted to follow a sample of 500 single-born Prematures and matched controls until age 12 to 13, and found their results to be generally congruent with the British studies. Performance deficits were noted on standardized tests well into early adolescence. Similar conclusions were drawn by DeHirsch, Jansky and Langford (1966), as premature children were noted to perform less well than controls on a wide variety of academic tests after their first and second year of school and well into their early adolescence.

Rubin, Rosenblatt and Balow (1973), also found that poor academic performance in the early years was noted in a greater proportion of low birthweight children and that this trend continued well into the later years. More recent studies have confirmed the earlier findings that low birthweight children are over-represented in special education classes and tend to score poorly on standardized tests well into adolescence. These findings serve to underscore the importance of conducting retrospective evaluations in addition to long-term outcome studies as most longitudinal studies tend to terminate at early adolescence.

More recent studies evaluating the relationship between perinatal complications and children's cognitive development have noted that infants who experience perinatal complications tend to manifest a disproportionately higher incidence of developmental delays. In a two-year study, Commey and Fitzhardinge (1979) found that 21% of the sample had major neurological anomalies, with 42% of these children displaying cognitive/developmental delays. In other words, approximately 50% of their sample of Prematures displayed behavioral difficulties that were clearly related to the presence of generalized CNS depression (severe hypotonia, absence of reflexes,etc.) on admission to the neonatal intensive care unit (NICU).

In a recent study which followed a group of premature children at 10 years following neonatal intensive care, Nickel, Bennett and Lamson (1982), noted that only 28% of those with birthweights of less than 1000 grams could be classified as normal, while another 28% of these children had developed some form of severe neurological disorder such as seizures, cerebral palsy, or hydrocephalus. This study further indicated that 64% of the total group required special education services at age 10, resulting from delays in mental development, reading comprehension, arithmetic reasoning, and mathematics achievement.

In another recent study (Pfeiffer, Herreman & Pfeiffer,1985) assessing the cognitive, behavioral, temperamental, and language functioning of preschool high-risk children (all with histories of prematurity and/or medical complications such as intraventricular hemorrhage, seizures, and perinatal asphyxia), it was noted rather clearly that these children were more likely to experience cognitive, neurodevelopmental, and behavioral problems later in life.

Premature Birth As A Sequelae to Learning Disabilities

Early research in the area of Learning Disabilities as a sequelae to prematurity focussed on I.Q. and scholastic differences between Prematures and full-term children, citing lower I.Q. and poorer scholastic performance for Prematures (Caputo & Mandell, 1970; Drillien, 1967; Harper & Wiener, 1965; Rabinovitch, Bibace & Caplan, 1961; Rubin, Rosenblatt & Balow, 1973; Siener, 1968; Wiener, 1962; Wiener et al, 1965;). Other research indicated no significant differences between I.Q. levels for Prematures and full-term children when corrected gestational age was used and very low birthweight infants were excluded from the sample (Churchill, 1965; Douglas, 1956; Drillien, 1961; Willerman & Chruchill, 1967). This is supported by current research in the field of Learning Disabilities in that intelligence alone does not distinguish Learning Disabled children from their non-Learning Disabled peers as both possess average intellectual capability. It is more appropriate to examine research pertaining to specific aspects of learning, including written and spoken language, mathematical ability, perceptual-motor functioning, and other academic skills when exploring the possible relationship between prematurity and Learning Disabilities.

Rabinovitch, Bibace and Caplan (1961) focussed on developmental milestones of preterms versus full-terms in an extensive retrospective study. In comparison with a control group, Prematures were delayed in walking, perceptual-motor functioning, and oral language development. Language comprehension, sentence elaboration, vocabulary, and word usage were notably weak for Prematures although no articulation or speech disorders were noted. It was concluded that linguistic immaturity illustrated by Prematures reflected lingering neurophysiological immaturity. Since language skills underlie much academic learning, it is conceivable that any deficit in language development may result in a variety of academic difficulties. Research with Learning Disabled children as early as the 1970's led to a general acceptance of the relationship between difficulties in language acquisition in the preschool years and subsequent language-based learning problems such as reading and spelling (Gaddes, 1980; Wiig, 1984). In addition, early research on language development among Prematures provided support for the hypothesis that these children, even at 5 or 6 years of age, had poorer language skills than their full-term counterparts (DeHirsch, Janski, & Langford, 1966; Erhlich, Shapiro, Kimball, & Huttner, 1973).

DeHirsch and Langford (1966) assessed behavior patterning, visuo-motor competence, oral language, and reading readiness at Kindergarten, Grade 1 and Grade 2. Uniformly poorer results were noted for Prematures with the greatest decrements found in oral language and reading readiness. Writing, spelling, and reading were significantly poorer at the end of Grades 1 and 2 for Prematures. Prematures also performed more poorly on tests of visual-motor integration and perceptual-motor tasks. The authors concluded that an absence of demonstrable early neurological defects did not preclude an absence of learning difficulties at school age. Subtle dysfunctions seemed to persist, especially with respect to higher cognitive tasks.

An early study investigating reading disabled boys of average intelligence but poor reading achievement noted that 11.5% of the poor readers were premature at birth while only 4.6% of the control group had been premature (Kawi & Pasaminick, 1959). This study confirmed earlier findings that poor readers are significantly more often Prematures, perhaps with more birth complications in their neonatal history, than good readers (Eames, 1945).

More recently, Hertzig (1981) noted a high number of neurological "soft" signs present in premature infants. Mild disturbances in visual-motor integration, fine-motor coordination, and perceptual disturbances are thought to reflect a primary disturbance of central nervous system organization in the strict absence of "hard" neurological signs such as seizures, hydrocephalus, and cerebral palsy. A high rate for the presence of these "soft" signs is also found among Learning Disabled children. An increased incidence of minor physical anomalies has also been noted for Prematures and Learning Disabled children (Von Hilsheimer & Kurko, 1971).

In a recent study examining language development in very low birthweight children (VLBW), Boswell (1987) found that in a sample of 5 to 6 year old children with VLBW performed significantly poorly on tests of language and cognitive ability when compared to normal birthweight peers. In fact, the low birthweight children selected from a hospital population (birthweight < 1501 grams) performed well below controls on two of the three language measures and poorly on all three of the cognitive measures. Clinically significant deficits were also identified in five of the 23 VLBW children, suggesting that the learning deficits often observed among these children frequently involve language-based deficits and also represent the most common pattern of Learning Disability. Since the sample was carefully selected to exclude children with more pronounced developmental deficits, and since significant impairment of language functions was still evident in the results, Boswell (1987) concluded that and "less carefully" selected sample of VLBW to include those who with more pronounced neurodevelopmental impairment, would have likely performed even poorer in her study. Despite the fact that SES factors were noted as the VLBW children from high SES backgrounds performed better than VLBW children from low SES, when compared to normals, Boswell (1987) concluded that no significant statistical interactions were noted between groups for SES on any language or cognitive tests. In addition, the research noted that since the sample was collected in Canada, where the general quality of health care is better, it represented a relatively advantaged group of children who despite this advantage, clearly demonstrated on-going deficits in language functioning seemingly independent of the environment they grew up in. The study concluded that VLBW children appear to remain at developmental risk at least until school entry, and quite consistent with reports of cognitive and academic difficulties from early follow-up studies (e.g., Douglas, 1960; Drillien, 1964; Wiener et al, 1968).

Summary of Selective Literature Review

Prematurity and Learning Disabilities

There is much that we do not know about the developmental outcome of premature birth. Despite the well-documented "high-risk" status of this group, clear prognostic data is extremely hard to establish, especially during the neonatal period. Biological, genetic, pathological, iatrogenic, and environmental considerations all interact to make research a difficult venture. From a medical perspective, only the most severe of enduring handicaps are clearly detectable during the first year of life. Such impairment might occur as a result of premature birth or medical complications or, as was mentioned previously, treatment-related effects. The relative incidence and severity of the damage is thought to relate to several factors, including degree of prematurity, level of neonatal care available at birth, type and severity of of complication(s), and subsequent socio-economic environment of the infant.

Early researchers attempting to explain developmental outcome focused their studies within the context of linear or main effect models, assuming that it was possible to specify specific events during pregnancy or delivery that would predict long-term outcome, regardless of other intervening variables (Gesell & Amatruda, 1941; Lubchenco, Delivoria-Papadopoulos, & Searls, 1972). The concept of a continuum of reproductive "wastage" was proposed by Lilienfeld and Parkhurst (1951), in an attempt to differentiate the importance of biological trauma on future outcome. This concept as well as other biologically driven models eventually proved to be central to the development of later theories that associated subtle neurodevelopmental deficits including minimal brain dysfunction with Learning Disabilities.

The major driving force of the large scale follow-up studies in the 50's and 60's was the development of a biological model that attempted to link major types of neurodevelopmental outcome with prematurity and establish low birthweight as a biological risk factor. These early attempts are exemplified by the Scottish studies (Drillien, 1964, 1967), the British Population Maternity Survey of 1946 (Douglas, 1956; 1960; Douglas & Gear, 1976), and U.S. based studies conducted in Baltimore (Harper & Wiener, 1965; Wiener, Rider, Oppel, Fischer & Harper, 1965; Wiener, 1968; Wiener, Rider, Oppel, & Harper, 1968). Attempts were then made to examine and refine the specific factors involved in outcome for these children including infant factors (precise birthweight, degree of prematurity), illness factors associated with prematurity (anoxia, respiratory distress), and treatment factors related to the medical care of Prematures (amount of oxygen needed, feeding practices). Specific outcome measures were also identified as researchers became interested in more subtle manifestations of brain dysfunction particularly those that related to school failure (Asbury, Orgill, Bajuk, & Yu, 1985; Lubchenco, Horner, Reed, Mix, Metcalf, Cohig, Elliot, & Bourg, 1973). During this period of research interest in premature outcome and learning deficits, two broad areas of investigation were followed including perceptual-motor dysfunction (Caputo, Goldstein, & Taub, 1981; Lis, 1969; Phillips, 1972), or more global deficits (Michaelis, Parmelee, Stern, & Haber, 1973).

The concept of minimal brain dysfunction associated with Learning Disabilities and resulting from low birthweight was firmly established by proponents of the biolo^ical model whose legacy continues to this day. Evidence connecting prematurity to brain damage as well as growth failure is well supported by several studies (Bjerre, 1975; Drillien, Thompson, & Burgoyne, 1980; Hack & Breslau, 1986). Early signs of subtle neurological dysfunction, which is frequently associated with transitory or benign problems in children with normal birthweight, has been found to be predictive of poorer outcome at later ages (Drillien, et at., 1980; Hack, DeMonterice, Merkatz, Jones, & Fanaroff, 1981; Jordan, 1971). Recent investigations have also found a proposed connection between more subtle neurodevelopmental deficit and school learning difficulties (Fawer, Calame, & Furrer, 1985; Hynd & Willis, 1988; Sameroff, 1986; Pape, Buncie, Ashby, & Fitzhardinge, 1978).

The second major approach to the study of long term outcome of Prematures was the additive model which highlights the relationship between birth condition and childhood functioning under the influence of intervening variables such as family background or socio-economic status (SES). The link between SES and prematurity as well as school achievement was well documented by Benton (1940), however, the strongest studies showing the effect of SES on outcome for Prematures were not conducted till the 1960's.

These retrospective studies reviewed thoroughly by Knobloch and Pasamanick (1966), identified social condition and premature birth as two major factors predictive of later outcome and suggested that SES and prematurity acted in an additive fashion to influence outcome. Specifically, Prematures at all levels of SES showed a deficit in performance relative to controls (Douglas, 1960; McDonald, 1967; Wiener, 1968). In some cases, researchers proposed that poor child-rearing conditions rather than low birthweight contributed to the outcome of Prematures and that SES also influenced outcome under an interactional rather than an additive model (Douglas, 1960). The general findings of the British studies were consistent with the view that low SES was linked to poor performance of Prematures on tests of cognitive and achievement status. In these studies, low birthweight children from high SES backgrounds were found to have no deficit by school age when compared to low SES Prematures (Drillien, 1967). These findings pointed to the increasing importance of background variables such as SES in relation to birth factors and led to the formulation of yet another model to explain outcome.

Sameroff and Chandler (1975) illustrated the third major approach to researching outcome among Prematures and proposed their transactional model which identified characteristics of the environment as being more important to outcome than any single critical incidents such as low birthweight. The most remarkable prediction of their theory was that exposure to a high SES environment would be sufficient to remove the effects of low birthweight by the time a child reached school age. The evolution of this as well as other models attempting to explain or predict outcome, reflected the increasing awareness of the effects of important environmental variables as well as the need for multiple predictors of childhood development. Although it is generally recognized that Prematures perform less well than their full-term counterparts, there is less agreement about whether these differences are due to biological factors, or to other equally important environmental factors (Field, 1980). The transactional model has found support in recent studies (Cohen, Sigman, Parmelee, & Beckwith, 1982), however, others have also pointed out that deficits in performance are still noted in Prematures who come from "middle" or better SES backgrounds (Boswell, 1967; Caputo, & Mandell, 1970; Drillien et al., 1980).

From an educational perspective, the major handicapping conditions of premature birth are the more subtle and "sub-clinical" neurological dysfunctions that are frequently manifested later in life. In reviewing the research, it appears plausible that these dysfunctions are etiologically linked to Learning Disabilities and are one of the major outcomes of prematurity (Pasamanick & Knobloch, 1961;Parmelee, Sigman, Koop, & Habner, 1975). These subtle neurodevelopmental deficits are difficult to detect at an early age by standard medical evaluation and most are not diagnosable with any degree of certainty until school progress has been evaluated. Standard psychological assessments may fail to establish an accurate diagnosis. Neuropsychological procedures must be employed if brain function is to be specifically measured within this population. More specifically, descriptive clinical studies are essential in order to document the needs and quality of future life for Prematures as this may be the only way to judge the relative efficacy of technological advancement medicine.

As noted by the literature review, premature infants consistently display a greater incidence of school-related problems than do their full-term counterparts (Astbury, Orgill, Bajuk, & Yu, 1986; Bell, Taylor, & Dockwell, 1985; Douglas, 1956; Lubchenco, Horner, & Feed, 1963; Weiner, 1968; Weiner, Rider, Oppel, & Harper, 1968). Deficits in such specific academic areas as reading, arithmetic, or written language are noted (Balow, Rubin, & Rosen, 1975-1976; Brown, Bendersky, & Chapman, 1986; Colletti, 1979; Davies, 1974; Drillien, 1980; Eames, 1945; Francis-Williams & Fitzhardinge, 1975; Grigoroiu-Serbanescu, 1984; Hubatch, Johnson, Kistler, Bruns, & Moneka, 1985; Hunt, Tooley, & Harvin, 1982; Jacob, Benedict, Roach, & Blackledge, 1984; Kawi & Pasaminick, 1959; Nobel-Jamieson, Lukeman, Silverman, & Davis, 1982; Siegel, 1983; Wierner, 1968). Deficits in intellectual functioning leading to the diagnosis of mental retardation are also documented (Ahman, Lazarra, & Dykes, 1980; Galter, 1982; Grigoroiu-Serbanescu, 1984). A number of investigations have been conducted on the physical, neurological, intellectual, behavioral, and school performance of very young, preschool, and school-age survivors of neonatal intensive care (Battle, 1987; Brown & Bakeman, 1980; Graham, Matarazzo, & Caldwell, 1956; Hertizig, 1981; Jacob, Benedict, Roach, & Blackledge, 1984; Koops & Battaglia, 1984; Lubchenco, Horner & Feed, 1963;

Pasamanick, Rogers, & Lilienfeld, 1956; Ross, 1987; Siegel, 1981; Von Hilsheimer & Kurko, 1979; Watt, 1987).

Although not all neonatal survivors display developmental deviations into school age, a description of neurodevelopmental performance that clearly differentiates many Prematures from full-term and healthy infants emerges. Recent research concludes that such differences may contribute etiologically to subtypes of Learning Disabilities, now viewed as a heterogeneous group of disorders. It follows then that the incidence of Learning Disabilities is expected to increase in the future for this population as the total number of infants surviving with both shorter gestational ages and lower birthweights increases.

It was hoped that the results of this study would establish valuable data related to psycho-educational diagnosis and treatment needs for these "high-risk" children. In addition, this study attempted to shed valuable light on the more subtle forms of brain dysfunction related to Learning Disabilities, cognitive impairment and psychopathology for older Prematures in comparison to normal birthweight children as this data is currently unavailable. The need for this information is clearly demonstrated in a variety of clinical and educational settings as the results would also be useful to professionals responsible for identifying, planning, and implementing effective early intervention strategies for such children. In addition, the results could also provide specific information regarding the possible etiology of Learning Disabilities; a handicapping condition affecting as many as one-third of all children.

CHAPTER III

RATIONALE AND HYPOTHESES

Definition of Terms

Learning Disability (also described as LD):

"Learning disability" is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and presumed to be due to Central Nervous System Dysfunction. Even though a Learning Disability may occur concomitantly with other handicapping conditions (eg., sensory impairment, mental retardation, social and emotional disturbance) or environmental influences (eg., culture differences, insufficient/inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences. (National Joint Council for Learning Disabilities, 1981)

"Learning Disorder" refers to any observed learning difficulty.
"Learning Disability" is a subset of Learning Disorders (as above).
"Specific Learning Disability" is a subset of Learning Disabilities and is specific to one or more academic areas (as above).

Developmental Disability:

A severe and chronic disability of a person which;
(a) is attributable to a mental or physical impairment or combination of mental or physical impairment;
(b) is manifested before the person attains age 22;
(c) is likely to continue indefinitely;
(d) results in substantial functional limitations in three or more of the following areas of major life activity (self-care, receptive

and expressive language, learning, mobility, self-direction, capacity for independent living, economic self-sufficiency);

(e) reflects the person's need for a combination and sequence of special, interdisciplinary, or generic care, treatment, or other services which are of lifelong or extended duration and are individually planned and coordinated. (Haring & McCormick, 1986).

Premature Infants (also described as Preterms, Prematures & Low Birthweight):

Infants who have completed less than 37 weeks of gestation or weigh less than 2500 grams at birth. They may also be referred to as low birthweight infants, preterms, or Prematures.

Subgrouping of Premature Infants:

Small for Gestational Age (SGA): Infants who are inappropriately small relative to their gestational age (<10th %'ile). This group can be further subdivided into those Prematures who are of Very Low Birth Weight (VLBW), weighing less than 1500 or 1000 grams.

Average for Gestational Age (AGA): Infants who fall within 2 standard deviations above or below the mean weight and length for their gestational age. These are also referred to as "normal" Prematures.

Large for Gestational Age (LGA): Infants who are inappropriately large (>90th %'ile) for their gestational age.

Very Low Birthweight Prematures (VLBW): Prematures with birthweights below 1500 grams.

Low Birthweight Prematures (LBW): Prematures with birthweights between 1500 and 2500 grams.

Gestational Age:

A specific calculation of gestation of the infant measured from the first day of the last menstrual period and expressed in completed days or weeks. It is also referred to as the "corrected age" as opposed to chronological age (age according to birth).

Neonatal Period:

The newborn period from birth to 29 days.

Perinatal Period:

The period shortly before (20 - 29 week of gestation) and after birth (1 to 4 weeks after birth).

High-Risk Infants:

Children who have abnormal perinatal or neonatal medical or environmental experiences that may increase their propensity for transient or long-term dysfunction.

Neuropsychological Assessment of Children

Since research indicates that Prematures are more at risk for developing Learning Disabilities, it follows that the need to carefully evaluate both the incidence and nature of Learning Disabilities within this population is of paramount importance. The neuropsychological approach, with its broad-based format, is the most comprehensive method to evaluate the needs of this group. This form of assessment has shown to be a useful procedure in delineating in more detail the cognitive processing deficits that often characterize LD populations than is often gleaned from traditional psychoeducational assessment (Reitan & Davidson, 1974; Rourke, 1985; 1991;Rourke, Fisk, & Strang, 1986).

Neuropsychology attempts to relate observable behavior to brain functioning and its main objective is to investigate the functional status of the brain through standardized measures such as behavioral responses on a variety of tests or test batteries. Neuropsychological assessment batteries are designed to assess global brain functioning as well as to evaluate the presence of deficits in specific areas of the cortex. The use of the test battery approach, as opposed to the single-test approach, is preferred as these batteries allow for a more comprehensive evaluation of a wide variety of skills. They are designed to provide reliable data from which valid descriptions can be made concerning the neuropsychological status of the subject. Because neuropsychological assessment integrates cognitive, sensori-motor, and emotional elements of behavior it represents the most comprehensive psychological evaluation available. A neuropsychological examination, with roots in both psychology and neurology, provides a theoretical structure in which neurologic, behavioral, and educational data may be synthesized into a comprehensive understanding of the subject. This descriptive data can then be used to design relevant rehabilitation or remedial programs for individuals.

Many of the assessment procedures used with children are, in fact, adaptations of earlier measures which have proven useful with adults. However, it must be kept in mind, that children are not merely "little adults". Developmental and environmental variables influence their performance on neuropsychological measures to such an extent that adult standards are often misleading with children. There are fundamental differences in the neuropsychological development and functioning of the child's brain versus that of an adult. These distinctions are important from an assessment perspective as they may lead to different diagnostic and prognostic issues which may then relate to the generalizability of results. Considerable caution must therefore be exercised in generalizing from adults to children regarding brain-behavior relationships.

From an anatomical point of view, the gross features of neonatal and mature brains are the same. The immature brain, however, undergoes considerable development consisting largely of increasing myelination and the development of neuronal pathways and redundant neuronal interconnections which characterize mature brain functioning. Brain development also involves the increasing functional importance of certain structures such as the corpus callosum, which is present at birth but is probably not functional (Dobbing & Sands,1973; Novick & Arnold,1988)).

Another area of difference between child and adult brain functioning is noted by observing the effects of injury. Damage or injury to the fully developed brain usually has some effect on the individual's behavior. When there is early insult to the brain regions whose functions are not yet developed, however, the effects of the resulting dysfunction are "silent" and may go unrecognized until the time that behaviors dependent on those structures are expected to emerge. This makes it difficult not only to detect early insult to the brain in children, but also to know whether impaired performance on tests is due to early insult or due to disturbed development.

Furthermore, the causes of brain dysfunction differ from adults to children. In adults, brain dysfunction resulting from some form of trauma is usually focal in nature, particularly in the case of cerebrovascular events, tumors, or penetrating head injuries. In children, however, brain insult, usually due to prenatal infections, chemical insults, perinatal trauma, intractable seizure disorders, or hereditary abnormalities, leads to more generalized or diffuse dysfunction and therefore may be less amenable to pathological diagnosis (Novick & Arnold,1988).

Differences between adults and children in neuropsychological skills can also be seen in intellectual functioning. Adult intellectual functioning depends heavily on experience and on the ability to store and retrieve acquired information and integrate new information. Children, lacking a vast store of acquired information, tend to focus their intellectual efforts on the acquisition of new information or new learning experiences. The ability to learn is fundamentally affected by brain dysfunction and as a consequence, the child may show a more serious disorder than the adult, if both suffer comparable brain insult. For example, if insult to the receptive language region is noted, the adult brain will primarily show dysfunction of receptive language skills, whereas the child's brain with its capacity to learn language skills interrupted, will likely show expressive as well as receptive language disturbances.

Finally, the performance of adults and children on test batteries may also differ, highlighting differences in neuropsychological functioning. As performance on tests is largely the function of the interaction of three factors, including test behavior, social/cultural influences, and underlying skills, it is often assumed that social/cultural and test behavior are constant over time for adults and therefore changes in test performance are assumed to be due to changes in the underlying skills. In children, however, test behavior and social/cultural influences cannot be assumed to be comparable as children are exposed to new experiences at school and demonstrate considerably diverse types of test behavior. In addition, the same tests do not measure the same domains of skill at different age level, as exemplified by the influence of language on the performance of nonverbal tasks for some children due to the development of linguistic skills. Performance is further influenced by changing strategies employed by the developing child.

Given these broad differences between adult and child brain functioning, neuropsychological evaluation can be a valuable tool in determining subtle forms of brain dysfunction while also highlighting the global or pervasive forms of impairment often noted among severely Learning Disabled children. The major advantage of using a neuropsychological approach in the assessment of neurodevelopmental disabilities among at-risk populations is that it incorporates a "battery" of tests. A broad-based neuropsychological battery is extremely useful as it considers a wider spectrum of cognitive-cortical functioning than accounted for by the traditional psychoeducational assessment (Hynd & Obrzut,1981b). This is particularly true for special groups of children such as Learning Disabled children who represent a large number of referrals in schools and other pediatric assessment facilities. The challenge in diagnosing and remediating LD is that these children represent a heterogeneous population who display varying deficits resulting from differing etiologies (Rourke,1975; Rourke, 1985; 1991). Neuropsychological procedures have not only contributed in the identification of specific and distinct subtypes of Learning Disabilities, but have also shown that this process can be accomplished in a reliable manner (Morris, Blashfield & Satz,1981; Rourke, 1985). The utility of using neuropsychological procedures in school psychology is further illustrated by a study which indicated that the use of neuropsychological data substantially increased a school psychologist's ability to predict academic achievement for LD children (Strom, Gray, Dean & Fischer,1987). The following study therefore employed the neuropsychological battery approach using the Halstead-Reitan Neuropsychological Battery for older Children (HRNB-C) as this battery has been extensively used and has clearly demonstrated its utility for evaluating brain-behavior relationships in children. (Reitan & Davidson, 1974; Rourke & Finlayson, 1978, Rourke, 1985; 1991).

Methodological Problems in Prior Research with Prematures

Variables in Prior Research

Studies conducted on premature infants often take into account 3 major classes of variables, including input, mediating, and output variables (Friedman, Chipman, Segal & Cocking, 1982). Input variables are indicators such as health status of the mother, health of the neonate, or environmental factors which are highly associated with the health status of the neonate. This health status can be given as an overall score by combining scores for respiratory, cardiac, or central nervous system assessments (such as the APGAR). Mediating variables are medical and/or psychological, familial, and social/environmental interventions. The later two variables include parental profession(s), income or education level, the infant/caregiver interaction, and home environment. Psychological intervention is often either stimulation programs for infants or parenting skills programs for parents. Outcome variables are medical and psychological functioning measures in terms of months or years following the neonatal period. Measurement of medical integrity is easily established, unlike psychological integrity which is more difficult to measure as it often refers to adjustment, temperament, and other behavioral variables. Performance on intellectual, achievement, or other cognitive/neuropsychological measures is therefore the focus of many outcome studies including the current study.

Despite the influence of input, mediating, and output variables, the influence of inter- and intraindividual differences among infants themselves, and the controversy concerning rate of handicap, it is evident that premature infants encounter a continuum of difficulties. This continuum has a significant impact on outcome and is a source of difficulty for most studies which examine discrete categories or sequelae by classifying the presence or absence of specific symptoms such as neurological handicapping conditions, mental retardation, or school achievement problems. Sequelae, however, do not occur in an unidirectional or "all or none fashion". Rather, a continuum of causality may exist at different levels of severity (Murphy, Nichter & Liden, 1982; Sameroff & Chandler, 1975). For the purposes of the current study, only the most obvious intellectual-cognitive or academic impairment was noted in addition to aspects of general emotional and behavioral functioning in relation to reported medical history and complications derived from the clinical interview or other historical data.

Developmental Continuity In Prior Research

Developmental continuity is another problematic area for existing research in this area. While it is generally true that some developmental functions, such as height and weight are continuous, many aspects of development are discontinuous or transformational. Studies which focus only on continuity may disregard vital information regarding how or when high-risk infants pass through such transformational developmental stages. Issues of developmental delay, dysfunction, or deficit may also apply to transformation in specific areas of functioning. Significant disabilities including Learning Disabilities which may not be amenable to early diagnosis, may emerge later in school-aged children, when greater demands are placed on higher (dysfunctional) brain functions. In fact, research conducted in the late 1970's and 1980's began to evaluate the relationship between dysfunction at different developmental stages and more subtle disabilities including Learning Disabilities. Presumably, these factors may play an even more important role in the long term outcome of Prematures who may show few "medical complications" or serious developmental problems and yet develop Learning Disabilities in school-age.

The current study assumes the existence of both developmental continuity and discontinuity since it was not a longitudinal investigation but more cross-sectional in its scope. The assumption is that preterm children may display a variety of deficits in various functions at different phases in life. The middle childhood to early adolescent phase (ages 9-14) was chosen for this study as most disorders related to development (developmental delay) or immaturity are less frequently diagnosed as the child is expected to have "grown out" of these problems by this time. On the other hand, a diagnosis involving a "deficit", "disorder, or "disability" is more frequently noted within this age range for precisely the opposite reason (ie., not due to developmental immaturity).

Correction for Prematurity in Prior Research

Many studies conducted after the early 1960's noted that premature infants often lagged behind their full-term counterparts in general development. This general delay was often evident until the preterm infant attained a chronological age of 2 to 3 years. Many authors therefore concluded that a correction for prematurity is necessary in situations where gestational age is important, such as in attaining developmental milestones (Dubowitz, Dubowitz & Goldberg, 1970; Palisano, 1986; Siegal, 1983). They argued that when corrected ages are used in re-examining such studies, significant discrepancies often disappear. They further noted that such age adjustments are needed until the age of 2 or 3, after which chronological age from birth may be used. Although this apparent "normalization" of Prematures by the ages of 2 or 3 has been argued in the research, there are subtle manifestations of outcome not easily detected if assessment is conducted solely at the neurological, intellectual, or behavioral levels. For the purposes of the current study however, chronological age from birth was used in the determination of actual age (uncorrected) as it was felt that older Prematures (ages 9-14) would not require the application of corrected age.

Experimental Designs of Prior Research

The large scale outcome studies published in the 1960's served to establish the link between low birthweight and long term developmental difficulties, even though the description and extent of these difficulties remained in question. Research methodology also appeared to increase in sophistication as more important variables were identified. The major methodological problems associated with studies of long term and short term outcome can be summarized under the two broad categories dealing with sample selection and choice of control groups.

A major problem with many studies has been the failure to take into account background variables related to the incidence and degree of low birthweight, and independently, to outcome variables. One previously discussed important variable is SES of the family. Although Benton in his classic study (1940) pointed out the possible confounding effects of background variables on outcome measures, researchers continued to ignore the problem. Other researchers did not include control groups or used inappropriate controls. In the absence of a control group, the standardization sample for a given test or group of tests is often used. Some have argued that while this procedure enables absolute deficit to be identified, this deficit cannot be specified in relation to children with similar backgrounds. This problem is generally alleviated if local normative distributions for a group of tests are available or if a Sibling Control group is used.

One might expect that the prediction of developmental outcome in premature infants could be readily solved by longitudinal research design. Indeed, longitudinal studies that carefully monitor the development of the infant past the infancy period and into early childhood are frequently viewed as the desired research strategy. These studies, however, are often plagued with design problems including small sample size, short follow-up duration, and unacceptably high attrition rate. A further problem encountered by these studies concerns the reporting of differences that greatly influence the apparent prognosis. In other words, some researchers included all children in their outcome measures of later developmental problems while others excluded those identified early as having major physical handicap but included those with major cognitive handicaps. Conducting thorough and sound longitudinal research is therefore a difficult proposition.

Matched cohort studies also appear to have limitations as differences in background variables between families of Prematures and their controls often contribute to differences on later examination. In order to combat this, some researchers suggested matching follow-up groups at the time of testing rather than at birth. An alternative to this approach has been to examine a selected group of low birthweight children and compare their performance with their own Siblings, although this type of study has not been conducted thus far. The major advantage of matched sibling controls is obvious as SES factors would apply to a much lesser extent as well as other background variables that have plagued cohort studies. The major disadvantage of sibling controls would be that not all children would meet the required age criteria for inclusion as a control subject or in some cases, may suffer the same type of genetic or familial disorder that could confound the results of the study. In any case, the following study chose to incorporate a sample of Siblings within the same age range as controls to account for a number of intra-individual variables.

Sample Selection in Prior Research

The other important methodological problem encountered in the research relates to sample selection. On the one hand, there appears to be considerable confusion in the research over the interchangeable usage of the terms "preterm", "premature", and "low birthweight. The term "premature" was used prior to the 1960's to denote babies who were considered ill-equipped to survive at birth due to immaturity related to early birth (Benton, 1940). Also at the time, a birthweight of less than 2500 grams was used as the criterion of biological immaturity by the World Health Organization (1948). It was noted, however, that many of these small infants behaved like mature babies that were born after normal gestational periods, thus making the term "premature" very misleading. In 1961, the World Health Organization changed the term to "low birthweight" but retained the defining characteristics (birthweight less than 2500 grams).

With further research conducted on this population, it soon became apparent that these children were indeed heterogeneous from a biological point of view as several subgroups existed based on the continuous variable of birthweight as well as groupings based on gestational age (Small for Gestational Age or SGA, Average for Gestational Age or AGA, and Large for Gestational Age or LGA). During the early period of research, two general groups were identified. The first group consisted of those children who were born too soon but appropriate in size for their gestational age (AGA), while the second group consisted of those babies who were small due to inadequate growth during the gestational period (SGA). This re-definition of low birthweight infants in terms of the joint criteria of gestational age and birthweight had important implications for future research which later concluded that broad differences existed between these two groups with respect to survival rate, neurological maturity, and incidence of handicap, with the SGA infants fairing much worse overall (Commey & Fitzhardinge, 1979; Ellenberg & Nelson, 1979; Francis-Williams & Davies, 1974; Neligan, Kolvin, Scott, & Garside, 1976; Schulte, Linke, Michaelis, & Nolte, 1969).

Additional research yielded further specification of the target population as it was found that not all low birthweight infants developed later developmental problems. Deficits in performance were usually found in only those infants born under 1500 grams while the largest group of low birthweight infants born between 1500 and 2500 grams, apparently showed few difficulties with respect to both mortality and morbidity (Drillien, 1964). Some of the more recent studies have selected only those infants with birthweights less than 1500 grams (Very Low Birthweight or VLBW) for follow-up investigation, and note that this subgroup is perhaps greatest in terms of risk factors due to neurodevelopmental immaturity. The major problem encountered in evaluating current research is that few, if any, VLBW children are identified in the sample selection thus reducing comparability between studies. Some researchers (Fitzhardinge & Pape, 1980) have suggested that the low birthweight infants at greatest risk are those who weigh less than 1500 grams and have gestational ages less than 33 weeks, as well as those with gestational ages less than 37 weeks and birthweight greater than two standard deviations below the mean (which usually results in a birthweight of less than 1500 grams). By far, however, the general standard with respect to defining Prematures as a large group appears to be birthweight less than 2500 grams and gestational age below 37 weeks, which was used for the purposes of this study (see Definitions). Normal sibling (controls) had gestational ages beyond 37 weeks and birthweight in excess of 2500 grams.

The current study was conducted on a volunteer (non-referred) sample of Prematures and their Siblings. This is consistent with most other educational and psychological research as there are considerably more demands placed on individual subjects than those required from subjects chosen to perform simple tasks such as surveys in which case random sampling could be employed. Informed consent and ethical guidelines pertaining to the assessment of children, in addition to increased demands required from the subject, were other factors that were considered when choosing volunteer subjects. Although pre-existing subject pools were available from local hospital follow-up programs, it was felt that the majority of these subjects may have had adverse medical conditions and may therefore represent a very biased sample of Prematures such as only those with physical and/or neurological deficits that require follow-up from the hospital. Volunteer subjects were also used as it was felt that a broader sampling of children was required in order to evaluate the more subtle types of dysfunction such as Learning Disability which is often described as affecting approximately 10% to 15% of the general population. Every effort was therefore made to include as many volunteer parents of Prematures as possible including those with no apparent "difficulties" either medically or from a psychological or educational perspective, despite the limitations involved in using volunteer subjects.

The rationale for direct solicitation of subjects from the general public was to try to avoid undue bias by selecting only hospital-based samples as they may have a greater incidence of medically-related difficulties at birth. Using only special education students would have also resulted in the selection of a biased sample. By direct solicitation, it is hoped that children with medical complications, Learning Disabilities, developmental disabilities, as well as "normal" Prematures (those having no identified problems) would be surveyed. The rationale for choosing sibling controls wherever possible was to evaluate and possibly control for SES factors and within-family differences and to serve as important subjects for comparative purposes. Normative (published) tables were also used as a comparative sample in order to rate the performance of all subjects on standardized instruments.

Current Research Hypotheses

As noted earlier, the aim of the study was to determine the extent and nature of Learning Disabilities including neuropsychological brain dysfunction, visual-motor deficits, behavioral and/or attentional disorders for a sample of children aged 9 - 14 with premature birthweight histories (n = 32) and compare them to a group of age-matched Siblings of normal birthweight acting as controls (n = 8). In addition to evaluating the performance of both groups of children, additional analysis was conducted within the Premature Group (Very Low Birthweight or VLBW <1500 grams, n = 12; compared to Low Birthweight or LBW 1500 - 2500 grams, n = 20), for the above variables, and in relation to the Sibling Control Group. The performance of this sample of "non-referred" Prematures, and Siblings was compared using standardized tests in accordance with published test norms and diagnostic rules for interpretation, in order to determine if the two groups differed significantly from each other with respect to the presence or absence of Learning Disabilities, presence or absence of brain impairment and/or cognitive dysfunction, presence or absence of visual-motor deficits, presence or absence of psychopathology, and the nature of such deficits, derived from neuropsychological test data. The first level of analysis used in this study explored differences between the two general groups of Prematures (n = 32) and Sibling Controls (n = 8), with respect to the above variables. The second level of analysis however, involved a further examination of the cognitive, academic and neuropsychological dimensions discussed above with respect to the performance of VLBW (n = 12) and LBW (n = 20) subgroups of Prematures in relation to the Sibling Control Group (n = 8). Additional comparisons were also conducted on a variety of variables related to the primary and secondary research themes.

The literature review identified a variety of earlier medical investigations that have been conducted on younger children and established a connection with learning and/or developmental disabilities resulting from premature birth, including subtle forms of dysfunction, as well as attentional and behavioral disorders. With the exception of a few early studies, the literature review noted that there has been a general lack of research conducted for older children with premature birth history, particularly with respect to the cognitive, academic or behavioral dimensions that appear to be very crucial as far as quality of outcome is concerned. In addition, no current studies were identified that incorporated neuropsychological procedures in studying older Prematures. Furthermore, there has been no research conducted comparing the neuropsychological performance of older Prematures to normal children; particularly Siblings who share the same socio-economic status and family environment. The current research was therefore undertaken to help fill this apparent void and to thoroughly examine a "non-referred" group of Prematures as prior studies tended to only focus on "high-risk" populations such as only those with obvious medical intervention histories.

In order to investigate the relationship between premature birth outcome with respect to cognitive, academic, neuropsychological and behavioral dimension, often implicated as etiological factors and/or characteristics of Learning Disabilities, the following research hypotheses were developed. Based on the notion that premature birth may result in more subtle or more global impairment of brain functioning particularly with respect to Learning Disabilities, the following hypotheses were created. These hypotheses are based on five major themes including Cognitive, Academic and Neuropsychological functioning, Visual-Motor functioning, and Behavioral functioning, as they relate to the broad field of Learning Disabilities. The Primary research hypotheses of the current study (Section I), included global comparisons or differences between the performance of the Premature Group in relation to the normal birthweight Sibling Control Group, in accordance with the five basic themes described above. Primary hypotheses were also constructed to evaluate the performance of the Premature Group ($n = 32$) with respect to birthweight and the above themes (Section I). A number of Secondary research hypotheses were also created in order to compare the performance of children within the Premature Group based on Very Low Birthweight (VLBW) versus Low Birthweight (LBW) subgroups, and the Sibling Control Group for the above variables (Section II). A description of the Primary (Section I) and Secondary (Section II) hypotheses is noted below. Additional comparisons were also conducted within and across the two groups of children although no specific research hypotheses were created in this regard (Section III).

Section I: Primary Research Hypotheses

The following hypotheses were created to investigate the broad cognitive dimensions using the WISC-R as a general index of mental ability consisting of both acquired or "crystalized" knowledge (ie., the Verbal scales) and more "fluid" problem solving skills (ie., the Performance scales) for Prematures versus Sibling Controls.

Cognitive Functioning Hypotheses (WISC-R)

In order to evaluate the cognitive ability dimension, a series of primary hypotheses were generated in order to compare the differences in mean IQ scores for Prematures versus Sibling Controls. Hypotheses were also created to investigate the relationship between birthweight and IQ and differences in WISC-R subtest scores by examining patterns that could be clustered into factors for both groups based on their performance on the WISC-R.

Hypothesis 1: Premature Birthweight vs. IQ

There will be significant relationships between birthweight and Verbal, Performance, and Full Scale IQ scores on the WISC-R for the Premature Group.

Hypothesis 2: IQ: Premature vs. Control Group

There will be significant differences in mean Verbal, Performance, and Full Scale IQ scores on the WISC-R between children from the Premature Group and the Sibling Control Group.

Hypothesis 3: Kaufman Factors: Prematures vs. Control Group

There will be significant differences in mean Verbal Comprehension, Perceptual Organization, and Freedom From Distractibility Factor scores on the WISC-R for children between the Premature Group and the Sibling Control Group.

Academic Functioning Hypotheses (WRAT-R)

A series of hypotheses were created to examine the academic ability scores of the Premature Group and the Sibling Control Group. Correlational analysis was conducted with respect to birthweight and children from the premature. Hypotheses were also created to compare the relative proportions of children from both groups that were classified as Learning Disabled in all subjects as well as in specific subjects, based on their performance on the WRAT-R.

Hypothesis 4: WRAT-R Subtests vs. Premature Group

There will be significant relationships between WRAT-R Reading, Spelling, and Arithmetic Test Scores, and birthweight of children in the Premature Group.

Hypothesis 5: WRAT-R Subtests: Prematures vs. Control Group

There will be significant differences in mean WRAT-R Reading, Spelling, and Arithmetic scores for children from the Premature and Sibling Control Groups.

Hypothesis 6: Special Education: Prematures vs. Control Group

There will be a significant difference in the proportion of children placed in special education settings between the Premature Group and Sibling Control Group.

Neuropsychological Functioning Hypotheses (HRNB)

A series of primary hypotheses were created to investigate the relationship between birthweight and neuropsychological performance of children from the Premature Group. Hypotheses were also created to investigate the performance of Prematures compared to Siblings on all major subtests of the HRNB-C.

Hypothesis 7: Birthweight vs. HRNB Composite: Prematures

There will be a significant relationship between birthweight and composite scores on the HRNB-C for children from the Premature Group.

Hypothesis 8: HRNB Composite: Prematures vs. Control Group

There will be a significant difference in mean composite scores for the HRNB-C for children from the Premature and the Sibling Control Group.

Hypothesis 9: Category Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Category Test error scores between children from the Premature and Sibling Control Group.

Hypothesis 10: Trail Making Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Trail Making Test Part A and Part B standard scores between children from the Premature Group and Sibling Control Group.

Hypothesis 11: SSPT / SRT Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Speech Sounds Perception Test / Seashore Rhythm Test standard scores of children between the Premature and Sibling Control Group.

Hypothesis 12: Tactual Performance Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Tactual Performance Test standard scores of children between the Premature and Sibling Control Group.

Hypothesis 13: Hand Dynamometer Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Hand Dynamometer Test standard scores of children between the Premature and Sibling Control Group.

Hypothesis 14: Finger Tapping Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Finger Tapping Test standard scores of children between the Premature Group and the Sibling Control Group.

Hypothesis 15: Grooved Pegboard Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Grooved Pegboard Test standard scores of children between the Premature Group and the Sibling Control Group.

Hypothesis 16: Aphasia Screening Test: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Aphasia Screening Test composite scores of children from the Premature Group and Sibling Control Group.

Hypothesis 17: Sensory-Perceptual Exam: Prematures vs. Control Group

There will be a significant difference in mean HRNB-C Sensory-Perceptual Exam composite scores of children from the Premature Group and the Sibling Control Group.

Visual-Motor Integration Hypothesis (Bender)

A single hypothesis was created in order to evaluate the global differences in visual-motor integration performance for both groups of children on the Bender-Gestalt Test.

Hypothesis 18: Bender Test: Prematures vs. Control Group

There will be a significant difference in mean Bender Gestalt Test standard scores for children from the Premature and Sibling Control Group.

Psychopathology/Behavioral Hypotheses (SIDAC)

A number of hypotheses were created to investigate the relationship between birthweight and psychopathology for both groups of subjects based on their clinical rating scores of the SIDAC. In most cases, the relative proportional differences in subtypes of psychopathology noted among the Premature Group and the Sibling Group were compared.

Hypothesis 19: Psychopathology: Prematures vs. Control Group

There will be significant differences in the proportions of children with a clinical rating of psychopathology on the SIDAC between the Premature Group and Sibling Control Group.

<u>Hypothesis 20: ADD-H: Prematures vs. Control Group</u>

There will be significant differences in the proportions of children with a clinical rating of Attention Deficit Disorder with Hyperactivity (ADD-H) on the SIDAC between the Premature Group and Sibling Control Group.

<u>Hypothesis 21: ADD: Prematures vs. Control Group</u>

There will be significant differences in the proportions of children with a clinical rating of Attention Deficit Disorder (ADD) on the SIDAC between the Premature Group and Sibling Control Group.

<u>Hypothesis 22: Conduct/Oppositional: Prematures vs. Control Group</u>

There will be significant differences in the proportions of children with a clinical rating of Conduct / Oppositional Disorder on the SIDAC between the Premature Group and Sibling Control Group.

<u>Hypothesis 23: Anxiety: Prematures vs. Control Group</u>

There will be significant differences in the proportions of children with a clinical rating of Anxiety Disorder on the SIDAC between the Premature Group and Sibling Control Group.

<u>Hypothesis 24: Depression: Prematures vs Control Group</u>

There will be significant differences in the proportions of children with a clinical rating of Depression on the SIDAC between the Premature Group and Sibling Control Group.

Section II: Secondary Research Hypotheses

Cognitive Functioning Differences: VLBW / LBW Prematures & Sibling Controls

In order to further evaluate the cognitive ability dimension of subgroups of Prematures in relation to Sibling Controls, a series of secondary hypotheses were generated comparing the differences in mean IQ scores.for Very Low Birthweight Prematures (VLBW), Low Birthweight Prematures (LBW), and Sibling Controls.

Hypothesis 25: FSIQ: VLBW / LBW / Siblings

There will be significant differences in mean Full Scale I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Hypothesis 26: VIQ: VLBW / LBW / Siblings

There will be significant differences in mean Verbal I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Hypothesis 27: PIQ: VLBW / LBW / Siblings

There will be significant differences in mean Performance I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Academic Functioning Differences: VLBW / LBW Prematures & Sibling Controls

A series of secondary hypotheses were created to examine the academic ability (WRAT-R) within the Premature Group with respect to Very Low Birthweight Prematures (VLBW), Low Birthweight Prematures (LBW), and the Sibling Control Group. Comparative analysis was also conducted with respect to the proportions of children displaying various Learning Disability subtypes, based on their performance on the WRAT-R and the WISC-R.

Hypothesis 28: Reading: VLBW / LBW / Siblings

There will be significant differences in mean WRAT-R Reading scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Hypothesis 29: Spelling: VLBW / LBW / Siblings

There will be significant differences in mean WRAT-R Spelling scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Hypothesis 30: Arithmetic: VLBW / LBW / Siblings

There will be significant differences in mean WRAT-R Arithmetic scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

Hypothesis 31: Global LD: VLBW vs. LBW Prematures

There will be significant differences in the proportions of children identified as Globally Learning Disabled (mean WRAT-R Reading, Spelling & Arithmetic standard scores <80 but Full Scale IQs >80) from the Premature Group with LBW (>1500 but <2500 grams), and VLBW (<1500 grams).

Hypothesis 32: Language LD: VLBW vs. LBW Prematures

There will be significant differences in the proportions of children identified as Language Learning Disabled (mean WRAT-R Reading &Spelling standard scores <80 but Full Scale IQs >80) from the Premature Group with LBW (>1500 but <2500 grams), and VLBW (<1500 grams).

Hypothesis 33: Math LD: VLBW vs.LBW Prematures

There will be significant differences in the proportion of children identified as Learning Disabled in Arithmetic (mean WRAT-R Arithmetic standard scores <80 but Full Scale IQs >80) from the Premature Group with LBW (>1500 but <2500 grams), and VLBW (<1500 grams).

Neuropsychological Functioning Differences: VLBW / LBW Prematures & Sibling Controls

A single hypothesis was created to investigate the relationship between birthweight and neuropsychological performance of subgroups of premature children (Low Birthweight or LBW, versus Very Low Birthweight or VLBW) and Sibling Controls on Composite scores of the HRNB-C.

Hypothesis 34: HRNB-C Composite: VLBW / LBW / Siblings

There will be significant differences in mean HRNB-C Composite scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group.

CHAPTER IV

METHOD

The study investigated a group of children aged 9 - 14 with premature birth histories using the Halstead-Reitan Neuropsychological Test Battery for Older Children (HRNB-C), as well as other tasks measuring academic achievement (WRAT-R), intellectual ability (WISC-R), visual-motor integration (Bender-Gestalt) and general psychological, developmental and behavioral functioning (Structured Interview), in order to determine the presence and nature of Learning Disabilities that may be attributable to subtle forms of brain dysfunction. The performance on this sample of Prematures (32 children) was compared to published test norms in accordance with standardized testing procedures and diagnostic rules for interpretation of the HRNB-C. The performance was also compared to a sample of Siblings aged 9 - 14 (8 children) with normal birth histories in order to determine if the two groups differed significantly from each other with respect to the presence or absence of Learning Disabilities including subtype analysis, presence or absence of brain impairment and/or cognitive dysfunction, and the nature of such deficits, derived from neuropsychological test data. A diagnostic assessment of psychopathology and/or behavioral/attentional deficits was also conducted for the two groups. The literature review indicated that while a variety of earlier medical investigations have been conducted on younger children and established a connection with physiological and/or developmental disabilities resulting from premature birth, more subtle forms of dysfunction including a variety of learning deficits, have not been thoroughly investigated using neuropsychological procedures. Furthermore, there has been no research conducted comparing the neuropsychological performance of older Prematures to normal children - particularly Siblings who share the same socio-economic status and family environment.

Description of Subjects

A sample of 32 children with premature birth histories were given a comprehensive clinical neuropsychological evaluation. All subjects in the Premature Group had birthweights below 2500 grams and/or were less than 37 weeks gestation at birth. The birthweights of the premature sample ranged between 928 grams and 3009 grams, with a mean of 1874 grams. Within the premature sample, there were 12 subjects who were classified as having very low birthweight (VLBW, <1500 grams), and 20 subjects classified as low birthweight (LBW, >1500 but <2500 grams) The gestational ages of the Premature Group ranged from 24 weeks to 40 weeks, with a mean gestational age of 30 weeks. These Prematures were born between 1976 and 1983 and were between the ages of 9 and 14 (mean age = 11 years), at the time of the investigation. The Premature sample consisting of 15 males and 17 females, were selected based on direct public solicitation (volunteers). All subjects in the Premature Group were attending school, however approximately 56.3% were enrolled in special education classes or received resource room assistance (N=18), while 43.8 % (N=14), were enrolled in regular classes. Grade placements for subjects in the Premature Group ranged from 3 to 10, with a mean grade level of 6. This sample also consisted of 26 right hand dominant individuals (81%) and 6 left hand dominant children (19%). The mean Full Scale IQ for the premature sample was 95, ranging from 65 to 123. Five subjects were adopted (16%) and there was one set of twins included in the sample. Nine of the subjects were living in a primarily rural setting (28%), while 23 subjects indicated and urban residence (72%).

Another group of 8 children were also selected as normal (control) Siblings whose birthweights were between 2897 grams to 4556 grams, with a mean birthweight of 3283 grams. The selection process involved volunteers who were the normal birthweight Siblings of the premature birthweight children within the same age group. All subjects within this Sibling group had gestational ages between 38 weeks and 41 weeks with a mean gestational age of 39 weeks. These subjects were also born between 1976 and 1983, with an age range of 9 to 14 (mean = 11 years), to match the subjects of the Premature group. There were 3 males and 5 females in the Sibling Control group.(birthweight = > 2500 grams, > 37 weeks gestation), also within the age range 9 - 14. All the subjects in the Sibling Control group were enrolled in school (grades range = 3 to 9, mean grade level = 5). However, none of the subjects were enrolled in special education classes or required any assistance. The mean Full Scale IQ for the Siblings was 107 with a range from 96 to 123. There were 6 subjects in this group who were right hand dominant (75%), while 2 subjects were left hand dominant (25%). There were no adopted or twin subjects in this sample and no medical complications were reported aside from 4 subjects (50%) who experienced a past history of ear infections. Approximately half of the Sibling subjects were living in a primarily rural setting (N = 4), when compared to urban settings (N = 4). The entire sample of subjects including subgroups of Prematures is summarized in Table 1 as follows:

Table 1. Description of All Subjects (N = 40)

Subjects	N	(%)
Premature Group	32	(80)
Males	15	(47)
Females	17	(53)
Low Birthweight Subgroup (LBW)	20	(50)
Very Low Birthweight Subgroup (VLBW)	12	(30)
Right Handed	26	(81)
Left Handed	6	(19)
Special Education	18	(56)
Regular Education	14	(43)
Rural Residence	9	(28)
Urban Residence	23	(72)
Adopted	5	(16)
Twins	1	(6)
Sibling Control Group	8	(20)
Males	3	(38)
Females	5	(62)
Right Handed	6	(75)
Left Handed	2	(25)
Special Education	0	(0)
Regular Education	8	(100)
Rural Residence	4	(50)
Urban Residence	4	(50)

Medical complications among the Premature sample were surveyed by requesting prior medical documentation and self-report during the clinical interview with the parents. The predominant medical history of this sample is summarized in Table 2 as follows:

Table 2. Reported Medical Complications (Premature Group)

Condition	N	(%)
Cerebral Palsy	2	(6)
Fetal Alcohol Syndrome	4	(13)
Closed Head Injury	8	(25)
Respiratory Distress Syndrome	11	(34)
Retrolental Fibroplasia	2	(6)
Seizure Disorder	6	(19)
High Fever (102+)	19	(59)
Ear Infections	26	(81)

Socio-economic status (SES) of the family

Family SES was assessed based on the educational level, occupational level and employment status of the major wage earner in the family. The educational and occupational headings used in this study were adapted from the Stanford-Binet IV Technical Manual (1986). Parental occupation was rated on an ordinal scale from high to low with Managerial / Professional at the top, followed by Technical / Sales, Service Occupations, Farming / Forestry, Precision Production, and finally Operators or Fabricators, as well as other similar professions. Parental Education was similarly rated from top to bottom based on level of post-secondary education with College Graduate or beyond at the top, followed by 1 to 3 years of College, High School Graduate, and finally, individuals less than High School Graduate.

The occupation level of parents in the Premature group included fathers who were mainly employed as laborers or fabricators (60%), as well as another large group who worked in the technical or sales field (26%). The mothers within this group were similarly employed mainly as laborers or fabricators (50%), and another smaller group who worked in the technical or sales field

(19%), as well as an additional group who worked in the service field (13%). A summary of parental occupation for the Premature Group is found in Table 3 below:

Table 3. Parental Occupation (Premature Group)

Occupation Level	Males	(%)	Females	(%)
Managerial / Professional	0	(0)	1	(3)
Technical / Sales	9	(28)	6	(19)
Service / Occupations	4	(13)	4	(13)
Farming / Forestry	0	(0)	3	(9)
Precision Production	0	(0)	2	(6)
Operator / Fabricator / Labor	19	(59)	16	(50)

The educational level of parents in the Premature group included fathers who had at least a high school education (47%), with a smaller group having at least 1 to 3 years of college (25%). However, a large number also indicated that they had less than high school education (28%). The mothers within this group showed more variation as most had less than high school education (56%), while some had high school (22%), and 1 to 3 years of college education (16%), or were college graduates (6%). A summary of the parental education levels for the Premature group is found in Table 4 below:

Table 4. Parental Education (Premature Group)

Education Level	Males	(%)	Females	(%)
College or Higher	0	(0)	2	(6)
1 to 3 Years College	8	(25)	5	(16)
High School	15	(47)	7	(22)
Less Than High School	9	(28)	18	(56)

The occupation level of parents in the Sibling Group included fathers who were mainly employed in the technical or sales field (63%), with another group employed in the service field (25%). The mothers within this group were similarly employed mainly within the technical or sales field (62%), as well as an additional group who worked in the service field (13%), or in farming (13%). A summary of parental occupations for the Sibling Group is found in Table 5 below:

Table 5. Parental Occupation (Sibling Group)

Occupation Level	Males	(%)	Females	(%)
Managerial / Professional	0	(0)	0	(0)
Technical / Sales	5	(63)	5	(63)
Service / Occupations	2	(25)	1	(13)
Farming / Forestry	0	(0)	1	(13)
Precision Production	0	(0)	2	(13)
Operator / Fabricator / Labor	1	(13)	1	(13)

The educational level of parents in the Sibling group included fathers who had at least a high school education (38%), with a larger group having at least 1 to 3 years of college (63%). The mothers within this group showed more variation as most had less than high school (38%), while some had 1 to 3 years of college (38%) or high school (25%). A summary of the parental education levels for the Sibling group is found in Table 6 below:

Table 6. Parental Education (Sibling Group)

Education Level	Males	(%)	Females	(%)
College or Higher	0	(0)	0	(0)
1 to 3 Years College	5	(63)	3	(38)
High School	3	(38)	2	(25)
Less Than High School	0	(0)	3	(38)

Research Design

Comparing Prematures to their full-term counterparts is an important method of evaluating the impact of premature birth on a wide variety of developmental and cognitive variables. As noted above, this type of research has already established important connections between learning disorders and prematurity. What has not been examined is the extent and nature of Learning Disabilities within the population of Prematures when compared to their normal Siblings and whether the learning disorders that these children display have any clear neuropsychological basis. The author therefore devised the following confirmatory descriptive, and qualitative study to investigate the extent and nature of neuropsychologically based learning disorders among an older group of Prematures in comparison to a small group of normal Siblings. The study used a retrospective design with descriptive statistics since the neuropsychological performance of these children is reflective of their birthdate and the available medical technology that was present at that time. Clinical retrospective studies such as this have the advantage of surveying a specified sample of individuals on a variety of dimensions if further information regarding this group is required. This format also provides valuable descriptive data concerning the occurrence and nature of a particular handicapping condition such as Learning Disabilities when specific performance is measured in relation to establish normative data in addition to matched Sibling groups. As mentioned previously, recent studies have noted that low birthweight children are over-represented in special education classes and tend to score poorly on standardized tests well into adolescence. In this manner, the specific needs of this subpopulation of children would be better identified.

Procedure

The aim of this descriptive confirmatory study was to evaluate these children on a variety of neuropsychological tasks (Halstead-Reitan Neuropsychological Test Battery for Older Children [ages 9 - 14], [HRNB-C]), as well as on tasks measuring academic achievement (Wide Range Achievement Test - Revised, WRAT-R), visual-motor integration (Bender Visual-Motor Gestalt Test, BVMGT), intellectual ability (Wechsler Intelligence Scale for Children - Revised, WISC-R), behavioral and emotional status (Structured Interview for the Diagnostic Assessment of Children, SIDAC), and general developmental and psychological functioning (Clinical Interview), with respect to the extent to which they met the criteria for a Learning Disability (LD), including subtype analysis in accordance with the classification system advocated by Rourke (1985). The presence or absence of brain dysfunction for both groups of children was also assessed using the classification system for the HRNB-C as outlined by Selz & Reitan (1979). In addition, the presence or absence of psychopathology for both groups of children was assessed based on the DSM-III criteria

The two groups of children (Ages 9 - 14) used in this study were created based on the presence or absence of a premature birth history. Children in the premature birth group (N = 32) all had birthweights below 2500 grams and/or had less than 37 weeks of gestation at birth. Children in the non-Premature group (N = 8) were Siblings with a normal birthweight history (> 2500 grams and/or > 37 weeks gestation at birth). Each subject was seen for approximately 7 to 8 hours based on at least 2 assessment sessions (parents were seen for an additional 2 sessions including initial interview and final debriefing). The first session included a structured clinical interview as well as initial assessment procedures. This was followed by a second assessment session (conducted within a two week period) involving additional tests. Debriefing with parents occurred following preliminary analysis on each subject and professional reports were prepared for each subject including all additional liaison with schools, medical personnel, or others as designated by the guardians. All assessments and interviews were conducted by the author with the assistance of trained test administrators for portions of the comprehensive test battery. The trained assistants did not have prior knowledge of which group of children they would be assessing or the parental occupation or educational level. The subjects were all assessed between the time period of 1991 to 1992 at a University clinic and training facility.

Both groups of children were administered the full Halstead-Reitan Neuropsychological Battery for Children including the WISC-R , WRAT-R, Bender, SIDAC and a Clinical Interview. The raw scores for a variety of tests were converted to standard scores (mean = 100, standard deviation = 15), using standardized procedure and age-appropriate published norms. The two groups of premature and non-premature (sibling control) children were then compared statistically (t-tests, anova with multiple comparisons, correlations, chi square) in order to determine if they differed from each other on a variety of variables including Academic Achievement (WRAT-R Reading, Spelling, Arithmetic scores), Visual-Motor Integration (BVMGT), Intellectual Ability (WISC-R Verbal, Performance, Full Scale scores), Neuropsychological performance (HRNB - C), and Behavioral Functioning / Psychopathology (SIDAC; CI).

Broad cognitive performance of both the Premature and Sibling groups, as well as a within-group comparison of VLBW and LBW (Premature group) was made with respect to mean differences on Full Scale, Verbal and Performance IQ. In addition, both the Premature and Sibling groups were compared on cognitive performance based on three factors outlined by Kaufman (19 79).

Both groups were also compared with respect to their performance on the WRAT-R subtests as an index of academic achievement. Learning disability criteria for Reading, Spelling and Arithmetic were established using standard scores and percentiles for each WRAT-R subtest . A standard score of 80 (1.33 standard deviation) was used as a criterion to form the Learning Disability groupings for each of the WRAT-R subtests, based on the classification system advocated by Rourke (1985). A second criterion for inclusion within the LD group was made based on Full Scale IQ scores at or above 80 (excluding those children with FSIQ at or below 79). A third criterion for inclusion within the LD group involved a clinical rating based on at least a 20 point difference between the Verbal and Performance IQ on the WISC-R, and a 20 point difference between each of the WRAT-R subtest scores in accordance with the particular subtype of LD being considered, as well as error patterns or other clinical observations that are commonly applied to determine subtypes of LD. This clinical rating of LD /non-LD was considered separately and was not statistically evaluated on its own since the statistical analysis yielded very similar groupings. WISC-R Verbal vs. Performance I.Q. scores were considered to be significantly different from each other based on one standard deviation (15 points) in either direction, although these discrepancies alone did not constitute inclusion within the LD group. The LD group was further divided into a Language LD (LLD) group by combining WRAT-R Reading and Spelling subtest scores. Subjects with poor performance on the Arithmetic subtest of the WRAT-R were considered to be a distinct subgroup of disabled learners (MLD). Both the Premature and the Sibling Group were compared on these variables as well as a within-group comparison between VLBW and LBW subgroups (Premature group) in relation to the Sibling Group.

Performance on the Bender Gestalt was evaluated based on standard scores with a mean of 100 and a standard deviation of 15. Impaired performance was based on the number of errors on the test protocol with standard scores at or below 70 as evidence of impaired performance while scores between 71 and 85 representing below average performance, and scores above 85 representing average or normal performance.

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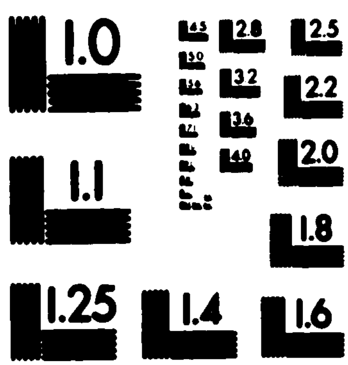
NBS 1010a ANSI/ISO #2 EQUIVALENT



PRECISION℠ RESOLUTION TARGETS

The neuropsychological performance of the Premature group and the Sibling group was compared using the HRNB-C. Poor performance including the presence or absence of brain dysfunction on the HRNB-C was based on established rules advocated by Selz & Reitan (1979), using an index of 37 rules which summarizes all HRNB-C performance for each subtest with four standard methods of inference (level of performance, right-left differences, patterns of performance, and pathognomonic signs) being applied. This system converts raw scores on each test variable to a set of 37 rules based on a four point scoring scale ranging from a score of 0 for adequate or normal performance; a score of 1 for performance slightly below normal standards; a score of 2 = for below normal performance but not indicative of clear brain damage; and a score of 3 for distinctly abnormal performance and the presence of brain damage. The Aphasia Battery was scored in a somewhat different manner, in which normal performance was scored 0, and abnormal performance scored 1, 2, or 3, based on the judged significance for impaired brain functions or deficit on that particular task for the age group employed. In other words, any errors on a relatively simple task such as letter recognition was scored 3 if failed, however errors on more difficult tasks for this age group such as spelling were scored 1.

These rules provide a convenient and reliable method for interpreting HRNB-C test results and, since they contain standard conversions for the test battery, performance norms are implicitly provided. Additional performance norms were also used with some norms based within the Canadian context (Klonoff & Low, 1974; Knights & Tymchuck, 1968, Spreen & Gaddes, 1969; Trites, 1977). These rules were found to reliably classify children into three groups (normal, Learning Disabled and brain damaged), with 73% accuracy, and appear to be sensitive to neuropsychological differences (Selz & Reitan, 1979). Cut off limits for the sum of these scores on any given individual were then calculated with scores of 19 or below for classifying normal individuals, scores of 20 to 35 for classifying LD children with perhaps some neuropsychological dysfunction, and scores at or above 36, as indicative of brain impairment. Based on these rules as well as by direct score comparisons with normative samples, each major subtest of the HRNB-C was compared across and within both groups including VLBW and LBW subgroups.

The structured interview (SIDAC) was summarized using DSM-III criteria and grouped according to particular manifestations of psychopathology as rated by the parents or through clinical observations (ADD, ADD-H, Anxiety Disorder, Depression, Conduct Disorder, Oppositional Deficient Disorder). An additional clinical interview conducted with the parents established early birth, developmental, social and general family and emotional history for each child in both groups (Prematures and Siblings).

Data Analyses

Data Analysis consisted of evaluating the presence or absence, as well as the degree of, brain dysfunction within this population of Prematures using descriptive statistics including frequencies, t-tests, chi-square, Anova, Multiple Comparisons, and correlations (Pearson, Point-Biserial) contained within the SPSS programs of the University of Alberta Computing System. The relative frequency and nature of Learning Disabilities was documented based both on the mean performance of children from both groups on the above test instruments and in relation to published test norms (Klonoff & Low, 1974; Knights & Tymchuk, 1968; Spreen & Gaddes, 1969; Trites, 1977). Subtypes of Learning Disabilities were also evaluated in relation to clinical patterns noted on selected neuropsychological tests as outlined by Rourke (1991a). Comparisons of mean scores for both groups were used in most cases with appropriate conversions to standard scores.

Variables

The data analyses consisted of determining the relationship of birthweight and comparisons between Prematures to Sibling Controls, as well as comparisons within the Premature Group (VLBW / LBW) to the Sibling Control Group using the following dependent variables: I.Q. scores (WISC-R subscale standard scores), Academic Achievement (WRAT-R standard scores), Visual-motor Integration performance (Bender-Gestalt standard scores), Neuropsychological performance (HRNB-C standard scores), and Emotional / Behavioral performance (rating scores on the SIDAC). Independent variables consisted of birthweight of the subjects, age, sex,SES factors or current grade placement.

Statistical Analyses

Statistical analyses consisted of the application of a variety of procedures suitable for the data being evaluated including, Analysis of Variance with Multiple Comparisons, t-test, Chi-Square, Pearson, Point-Biserial correlation, and Frequencies.

Measuring Devices

Comprehensive test battery

The following tests were administered to subjects in the following order:

Visual-Motor Integration Tests:
Bender Visual-Motor Gestalt Test (BVMGT)
Academic Achievement Tests:
Wide Range Achievement Test - Revised Part I & II (WRAT-R)
Intelligence Tests:
Wechsler Intelligence Scale for Children - Revised (WISC-R)
Neuropsychological Tests:
Halstead-Reitan Neuropsychological Test Battery for Children (Ages 9-14) (HRNB-C)

- Hand Dynamometer Test (HDT)
- Finger Tapping Test (FTT)
- Grooved Pegboard Test (GPT)
- Tactual Performance Test (TPT)
- Trail Making Test (TMT)
- Speech Sounds Perception Test (SSPT)
- Seashore Rhythm Test (SRT)
- Category Test - Intermediate Booklet Form (IBCT)
- Reitan-Klove Sensory Perceptual Examination (SPE)
- Aphasia Screening Test (AST)

Behavior/Personality Measures:
Structure Interview for Diagnostic Assessment for Children (SIDAC)
Clinical Interview (CI)

What follows is a brief description of the tests used in the study. They appear in random order but are grouped together in the case of the HRNB-C.

Description of Tests

The Halstead-Reitan Neuropsychological Test Battery (HRNB)

A comprehensive neuropsychological test battery must meet certain criteria in order to be useful for diagnosis and treatment selection Golden,1976; Rourke,1976). In this regard, at least three important criteria need to be met, namely comprehensiveness, sensitivity to the domain sampled, and validity. Comprehensiveness refers to the battery's ability to assess the full range of abilities subserved by the brain, including higher and lower cerebral functions. This would include dive se sensory and motor functions in the auditory, visual, and tactile modalities, cross-modal integration, abstract and conceptual reasoning, intellectual and academic functioning, language and memory, spatial concepts, and emotional functioning. Sensitivity refers to the battery's ability to detect general or overall brain functioning as well as the capability of detecting deficits in particular parts of the brain. In this manner, the battery could be used to screen for the presence or absence of brain impairment as well as to permit the differentiation of sensory and motor functions involved in the perception and/or execution of a given task, for example. Validity refers to the inclusion of standardized and objective measures of a broad range of language, verbal and nonverbal reasoning, and auditory and visual memory functions that are amenable to neuropsychological inference, interpretation, and prediction.

With respect to meeting the previously outlined criteria for a comprehensive neuropsychological test battery, the HRNB easily satisfies the first two criteria of comprehensiveness and sensitivity. In general, the HRNB measures abstraction, concept formation, visual-spatial and spatial-kinesthetic problem-solving, attention and discrimination, memory, language skills, and sensory-perceptual and motor skills. In addition to these measures, other allied tests are incorporated in the battery, including the Wechsler Intelligence Scales, Minnesota Multiphasic Personality Inventory (MMPI), Wide Range Achievement Tests (WRAT), Lateral Dominance Examination, Wechsler Memory Scales, because of their sensitivity to certain types of functioning and their ability to discriminate between various disorders when interpreted with the HRNB. In this manner the broad range of abilities as well as specific areas responsible for particular functions are thought to be tapped. In addition to sensitivity, a good neuropsychological test battery should be able to measure these diverse functions as distinctly as possible. In this regard, a recent study with children found that at least 90% of the variability of the HRNB was found to be non-redundant with the functions measured by the WISC-R, whereas the overlap that did occur was largely attributable to "general" cognitive ability in each measure (D'Amato, Gray & Dean,1988).

The HRNB also appears to satisfy the third and perhaps most important criteria of validity, including the ability to provide neuropsychological [illegible] regarding underlying deficits. In this regard, Reitan has developed an [illegible] method of interpretation for his test batteries based on [illegible] of inference. The purpose of this approach is to adapt and improve [illegible]nical methods of inference by classifying children according to a system of rules These taxonomic rules (Selz & Reitan,1979), include level of performance (normative data), patterns of performance among various tests (relationships among various tests), right-left differences (comparison of performance on the two sides of the body), and pathognomonic signs (performance is either normal or deviant). Using a statistical model of incorporating all four methods of inference would then allow for a more comprehensive analysis of neuropsychological test results than would a system which relied on one method alone, leading to an improved degree of success in classifying individuals into appropriate categories.

The HRNB is also perhaps the most widely used and best known comprehensive battery of neuropsychological functioning. The majority of the tests within the battery are adaptations of existing clinical and experimental measures. The current battery consists of 10 measures which were shown to be the best discriminators of brain damage (Reitan,1969; 1979a). Originally, the HRNB was designed for adults (over 15 yrs). Between 1951 and 1953, however, Reitan modified and extended the adult battery downward and an older children's version (ages 9-14) was developed from research using younger subjects (Reitan, 1969). This version, known as the Halstead-Reitan Neuropsychological Test Battery for Children or HRNB-C, retains basically the same measures as the adult battery except that it incorporates test items suitable for children, including an age-appropriate version of the Wechsler scales (WISC-R).

Validation studies have repeatedly shown both versions of the HRNB to be sensitive to cortical dysfunction (Boll,1981; Nici & Reitan, 1987; Reed, Reitan & Klove,1965; Reitan, 1979b). The battery has a high accuracy rate (>90%) in discriminating normal controls from neurological patients (Kelly & Dean,1990). Its usefulness in the assessment of pediatric populations has also been well documented (D'Amato, Gray & Dean,1988; Reitan, 1981, 1982, 1984; Selz, 1981; Selz & Reitan, 1979).

As mentioned earlier, individual tests comprising the HRNB were selected on the basis of their ability to discriminate between normal controls and brain damaged patients. In the development of the test battery, specific testing procedures were included based on empirical displays of their sensitivity to brain dysfunction. Neuropsychological inferences were then made relative to correlations between scores and an independent neurological diagnosis. The HRNB-C tests represent a downward extension of the HRNB to incorporate age-appropriate tasks. The subtest are briefly discussed below:

<u>Aphasia Screening Test (AST)</u>

Reitan developed this test by modifying Wepman's Aphasia Screening Test for receptive and expressive aphasia. This screening test briefly measures the various major language functions as well as visual-constructional and motor apraxia. The major language functions surveyed include naming, spelling, repetition, reading, comprehension, simple memory, writing, enunciation, and calculation. There are tasks that assess left-right orientation and the ability to follow oral commands. The subject is also asked to demonstrate the use of a familiar object and to copy simple geometric designs. This test requires 10 to 15 min. to administer and consists of 32 items. The results obtained with this screening measure provide information regarding the functioning of the right and left hemispheres. Specific signs of deficiencies usually warrant a more thorough investigation.

Reitan-Klove Sensory-Perceptual Examination (SPE)

This series of examinations evaluate tactile, auditory, and visual perception both unilaterally and bilaterally in order to investigate the presence or absence of sensory suppressions. Tactile perception is assessed unilaterally by touching the subject's hand or face while the eyes are closed. The subject must indicate which side of the body has been touched, and whether double simultaneous (hand-hand or hand-face) stimulation has been presented. In this manner, one can determine if the subject has right or left-sided tactile-perceptual difficulties (suppressions). Auditory perception is assessed by presenting a soft stimuli behind the subject's back both unilaterally and bilaterally, again to check for suppressions. Visual perception is measured by having the subject determine whether the examiner is moving one or two hands from a peripheral level (above, at, or below eye-level quadrants), again to check for the presence of suppressions in the visual field. These sensory exams are sensitive to parietal, temporal, and occipital lobe functioning respectively and provide methods for lateralizing and localizing brain damage.

Tactile Finger Localization (TAFL)

This test assesses tactile localization (agnosia) by having the examiner alternately touch the subject's fingers (bilaterally) and having the subject correctly identify them without the use of vision. Lateralizing signs for parietal lobe integrity are measured by this test.

Finger-Tip Number Writing Perception Test (FTNW)

Complex tactile-perceptual skills are measured by this test as the examiner traces a series of numbers in a prescribed order on each of the subject's fingers. Prior to beginning the test, large versions of the same numbers are written on the subject's palms while blindfolded. As with the previous tactile-kinesthetic awareness tests, this subtest is sensitive to parietal lobe dysfunction and is often performed poorly by children with language-related Learning Disabilities.

Tactile Form Recognition (TAFR)

On this task the subject is required to place one hand through an opening in a board while the examiner places geometric shapes into the subject's hand one by one. The subject must then point to the same shape placed on top of the same stand (which hides the objects from view) with the other hand. Both hands are tested for tactile discrimination as well as speed of response and right-left differences. This test is designed to measure the general integrity of the contralateral parietal lobe.

Hand Dynamometer Test (HDT)

This test employs a calibrated hand dynamometer to assess an individual's strength of grip bilaterally. Traditionally, this measure has been used to assess the integrity of the frontal lobes as deviations from the expected pattern of performance for preferred versus nonpreferred hands may reflect lateralizing signs. Interpretations using this test take into account an individual's sex, occupation, level of education, history of peripheral injury, and age.

Finger Tapping Test (FTT)

This test requires individuals to tap a key-like lever (attached to a mechanical counter) as rapidly as possible using the index finger of their right and left hands over several trials. This test assesses motor speed and coordination and allows for a comparison of the relative performance of the right and left hands. As with the HDT, deviations from normal performance with the preferred versus nonpreferred hand, offer good lateralizing indicators of the functional integrity of the frontal lobes.

Grooved Pegboard Test (GPT)

Although this test was not included as part of the original HRNB, it has been incorporated into the battery as it involves the rapid placement of small pegs into a board containing grooved slots that are oriented in different directions. Time scores are noted for trials using the right and left hands. As noted earlier, this test evaluates fine motor dexterity and speed and, like other motor tests of the HRNB, deviations from normal performance with the preferred versus nonpreferred hand offer good lateralizing indicators of the functional integrity of the frontal lobes.

Tactual Performance Test (TPT)

This test is a modified version of the Seguin-Goddard Form Board. It utilizes a form board and 10 geometrically shaped blocks (6 blocks for the HRNB-C), that fit into cut-out recesses. The subject is blindfolded and never allowed to see the board and instructed to place as many blocks into their proper locations as quickly as possible, first using the dominant hand, then nondominant hand, and finally both hands simultaneously. The time to completion (to a maximum of 10 minutes for each trial) is recorded. After all three trials are completed and the form board placed away from the subject's view, the subject is asked to draw an outline of the form board and indicate the shape and location of the blocks from memory. The TPT measures the child's tactile discrimination, manual dexterity, kinesthetic functions, spatial abilities, and incidental memory. This test is a good discriminator of neurologically impaired individuals and appears to be particularly sensitive to parietal lobe dysfunction. In addition, time differences between trials for the preferred and nonpreferred hands provides clues regarding lateralization. The Memory score reflects tactual memory for shapes while the Localization score reflects complex tactual-spatial memory and is therefore sensitive to lesions in the temporal-parietal region. Due to the number of trials using the dominant and nondominant as well as bilateral hand performance, the TPT also assess motor learning and may provide clues to the integrity of the corpus callosum.

Speech Sounds Perception Test (SSPT)

This test requires that the subject listen to an audio tape consisting of a series of 60 nonsense syllables. A single stimulus is presented and the subject is required to choose from 1 of 4 alternatives (1 of 3 for the HRNB-C). This test measures auditory verbal skills, cross-modal skills (auditory-input-visual-output), and the ability to discriminate between similar sounding syllables. It is also a useful test of attention and concentration skills as subjects are required to attend to a mechanically delivered and somewhat repetitious task. It is sensitive to brain impairment in general but significantly low scores often indicate global dysfunction of the left or right hemisphere, particularly with respect to the temporal lobe region.

Seashore Rhythm Test (SRT)

This test was originally adapted from the Seashore Test of Musical Talent. Like the SSPT, this test requires the subject to listen to a standardized tape recorded presentation of 30 pairs of rhythmically patterned sounds, and indicate whether they are similar or dissimilar. This test measures sustained attention and concentration ability as it is relatively nonstructured and delivered at a quick pace. As such, it is a good indicator of generalized brain impairment. It also requires recognition, perception, and discrimination of symbolic sound patterns that are nonverbally-mediated and therefore is sensitive to dysfunctions of the nondominant hemisphere and, in particular, the temporal lobe region.

Trail Making Test (TMT)

This is a two-part timed paper and pencil test. Part A consists of circled numbers randomly scattered and the subject is required to order them in the correct sequence by drawing a line among them as quickly as possible. Part B is essentially equivalent except that both numbers and letters of the alphabet are randomly scattered and the subject is required to alternately connect a number and then a letter in the correct sequence as quickly as possible. Part A provides a good measure of attention and concentration skills as well as visual scanning ability, tracking, and sequencing skills, and is sensitive to brain dysfunction in general. As it incorporates numerical information and involves the use of visual scanning, it also appears sensitive to nondominant hemisphere deficits. Part B measures attention and concentration as well as more complex visual sequencing skills including the ability to process both language-related information (letters) and nonverbal information (numbers) in rapid format. Due to its requirement of cognitive flexibility, it is highly sensitive to brain dysfunction in general and deficits involving the language dominant hemisphere, in particular.

Halstead Category Test (HCT)

This test is a concept-identification procedure in which the subject must discover the concept or principle that governs the relationship between various series of geometric forms. The stimuli (which can be presented through the use of a projection screen or in a booklet format as in the Booklet Category Test {Intermediate Booklet Category Test (IBCT)- HRNB-C}), are presented visually to the subject who is told that the point of tne test is to see how well he or she can learn the concept or principle that underlies the geometric forms in each of seven subgroups (6 for the HRNB-C). The subject's effort is facilitated by the provision of feedback concerning the correctness of responses. The number of error scores are analyzed using either a norm-referenced approach or a clinical cut-off approach to establish the presence or absence of brain impairment. This test measures nonverbal abstract reasoning logical analysis, cognitive flexibility, and conceptual problem-solving ability. It requires the subject to generate possible solutions based upon concepts that he/she formulates and then modifies based upon corrective feedback. As such, it is a very good discriminator of brain dysfunction in general. It is also considered to be a good predictor of everyday problem-solving skills involving the ability to learn and benefit from situational feedback.

Wechsler Intelligence Scale for Children - Revised (WISC-R)

The WISC-R is perhaps the foremost individually administered measure of children's intelligence. It is based on Dr. Wechsler's concept of intelligence as a multifaceted overall or global entity that can be inferred from a child's performance on a series of tasks, both verbal and nonverbal. The Verbal Scales measure the child's understanding of verbal concepts and his/her ability to respond orally to questions that tap acquired knowledge, short term memory, analogous reasoning, social knowledge, and expressive vocabulary. The Performance Scales measure the child's ability to solve problems requiring visual-spatial reasoning, manipulation and fine motor coordination, visual discrimination, inductive and deductive reasoning, puzzle assembly, and visual associate learning including perceptual speed. Deviation I.Q.s are provided for the Verbal, Performance, and Full Scale Scores.

Bender Visual-Motor Gestalt Test (BVMGT)

The BVMGT is useful as a maturational test of visual motor gestalt function in children and adults and is often included in a standard neuropsychological battery. It consists of a series of nine figures, each printed on a separate card. The examinee is required to reproduce each figure as he/she observes it. The test shows the maturational level of visual motor perception, which is associated with language ability and with various functions of intelligence including visual perception, motor coordination, memory, temporal and spatial concepts, and organization or representation. It has also been useful in the diagnosis of organic deficits.

Wide Range Achievement Test - Revised (WRAT-R)

This is a widely used test of academic achievement in reading (word recognition), spelling, and arithmetic. First published in 1936, it has been revised five times and examined extensively over the past 40 years. It has also been used in conjunction with most neuropsychological evaluations and published test norms are provided with respect to its use with the HRNB-C. The WRAT-R (1984) includes separate test forms for Level I (ages 5-0 to 11-11 years) and Level II (ages 12-0 to adult). It yields raw scores, grade equivalents, standard scores, and percentiles. Despite criticisms regarding its U.S. normative base and its limited samples of such broad skills as "reading", the WRAT has been consistently used in neuropsychological research and therefore provides an important research base for any future comparative studies. In a recent study examining the clinical and research utility of the WRAT in comparison to the WISC-R with respect to discrimination power for neuropsychological impairment among normal and LD children, it was noted that the WRAT appeared to be a better predictor of neuropsychological performance than the WISC-R (Davis, Dean & Krug, 1990).

Structured Interview for Diagnostic Assessment of Children (SIDAC)

The SIDAC is a modified and updated version of the Kiddie - Schedule for Affective Disorders and Schizophrenia (K-SADS) (Puig-Antich & Chambers, 1978). It provides a structured interview format using DSM III or DSM III-R diagnostic criteria, in order to screen for the presence or absence of clinical psychopathology in children ages 6-12.

Clinical Interview (CI)

The CI was developed by the author as a structured interview designed to gather information pertaining to the developmental, medical, educational, social, and family history of children and their families.

CHAPTER V

RESULTS

Summary of Results

This study was aimed at evaluating a group of older premature birthweight children on selected cognitive, academic, neuropsychological and behavioral measures with respect to Learning Disabilities, as well as cognitive and neuropsychological brain dysfunction and to compare their performances with selected Siblings who were not born prematurely. The initial investigation involved the administration of the full Halstead-Reitan battery including the WISC-R , WRAT-R . Bender Gestalt, and a structured interview for all children classified as having a premature birth history (< 2500 grams and/or < 37 weeks gestation, N = 32), as well as their Siblings within the same age range (9 - 14) with normal birth histories (> 2500 grams and/or > 37 weeks gestation, N = 8). The two groups of premature and non-premature (sibling) children, as well as premature children with very low birthweight (<1500 grams; VLBW) or higher birthweight (>1500 but <2500 grams; LBW) were then compared statistically in order to determine if they differed from each other (and/or the Sibling Group) on a variety of variables including academic achievement (WRAT-R Reading, Spelling, Arithmetic scores), Intellectual Ability (WISC-R Verbal, Performance, Full Scale scores), Visual-Motor Integration (Bender Gestalt), Neuropsychological performance (Halsteat-Reitan Battery), and Behavioral / Psychopathology Indicators (Structured Interview using DSM-III-R criteria).

It was hypothesized that children from the Premature Group and the Sibling Control Group would differ in their performance on the above measures and that the Prematures would likely display lower IQ and more variation between VIQ/PIQ, more indicators of a Learning Disability including certain subtypes of LD, more indicators of brain dysfunction on the HRNB, more indicators of visual-motor integration deficits and more indicators of psychopathology and/or attentional deficits when compared to a sample of Siblings acting as controls (Sibling Group) who would not display these deficits.

It was further hypothesized that children from the Premature Group would display more specific patterns of Learning Disability, particularly in mathematics, including more variation in Verbal or Performance I.Q., with perhaps lower Performance IQ, differences in WISC-R Factor scores, more impaired performance on the HRNB particularly for complex nonverbal and abstract reasoning skills, more dysfunction in basic sensory-perpceptual skills, and more indicators of psychopathology including attentional deficits, when compared to children from the Sibling Group with normal birthweight. In addition, it was hypothesized that the Very Low Birthweight Prematures (VLBW = <1500 grams) would likely display more deficits on all the above variables when compared to Prematures with Low Birthweight (LBW = 1500- 2500 grams), and in comparison with the Sibling Group, who would likely not display deficits in all or any of the above variables. A Sibling Control Group was used primarily to try to control for socio-economic factors which often account for the lion's share of variability between groups used in previous studies.

Raw scores for the test battery were converted to standard scores (mean = 100, standard deviation = 15), using standardized procedure and age-appropriate published norms. Learning disability criteria were established using standard scores for each WRAT-R subtest (standard scores < 80 and Full Scale IQ >80). Global LD was categorized by low performance on all three WRAT-R subtests (standard scores <80, FSIQ >80); Language LD was categorized by Reading and Spelling performance (standard scores <80, FSIQ >80); Arithmetic LD was categorized by Arithmetic performance (standard scores <80, FSIQ >80). Verbal vs. Performance I.Q. scores were considered to be significantly different from each other based on one standard deviation (15 points) in either direction. Poor performance including the presence or absence of brain dysfunction on the HRNB-C was based on established rules using and index which summarizes all HRNB-C performance (Index Scores < or = 19 = normal; Index Scores between 20 - 35 = Learning Disabled; Index Scores at or > 36 = Brain Damaged). Visual motor integration was assessed using standard scores for the Bender Gestalt (< 80 = Abnormal; >80 = Normal). The structured interview (SIDAC) was summarized using DSM-III criteria and grouped according to clinical features (rating) of psychopathology (ADD, ADHD, Anxiety Disorder, Depression, Conduct / Oppositional Deficient Disorder.

The data was analyzed statistically (t-test, ANOVA with Multiple Comparisons, Pearson r, Chi-square, Frequencies) based on Primary and Secondary research hypotheses that were grouped according to five general themes including (1) Cognitive performance, (2) Academic performance, (3) Neuropsychological performance, (4) Visual-motor integration performance, and (5) Behavioral/Psychopathology indicators. Primary hypotheses compared the performance of the Premature group and the Sibling Control group with respect to the above themes, while Secondary hypotheses involved internal comparisons within the Premature group (LBW vs. VLBW) in relation to the Sibling Control group for the first three themes.

The results of the study provided support for most of the Primary and Secondary hypotheses (Section I and II of this chapter) as summarized in Table 7 below. No significant differences between the Sibling Control Group and the published test norms were noted on any of the variables studied. It was concluded that the Sibling Group's performance approximated the performance of normals.

Table 7. Research Hypotheses Summary

Hyp. #	Description	Statistics	Results
Section I. Primary Hypotheses:			
1	Birthweight / IQ; Prematures	Pearson r	Sig.*
2	IQ; Prematures / Siblings	t-test	SD*
3	IQ Factors; Prem. / Siblings	t-test	SD*
4	WRAT-R / Prematures	Pearson r	Sig.*
5	WRAT-R; Prem. / Siblings	t-test	SD*
6	Sp. Educ.; Prem. / Siblings	Chi-Square	SD*
7	Birthwt. / HRNB comp.; Prem.	Pearson r	Sig*
8	HRNB comp.; Prem. / Siblings	t-test	SD*
9	Category; Prem. / Siblings	t-test	SD*
10	Trail Making; Prem. / Siblings	t-test	NS
11	SSPT, SRT; Prem. / Siblings	t-test	SD*
12	Tactual Perf.; Prem. / Siblings	t-test	SD*
13	Hand Dyn.; Prem. / Siblings	t-test	ND
14	Finger Tap; Prem. / Siblings	t-test	SD*
15	Grooved Peg; Prem. / Siblings	t-test	SD*
16	Aphasia Screen; Prem. / Sibs	t-test	SD*
17	Sensory Percep; Prem. / Sibs	t-test	SD*
18	Visual-Motor; Prem. / Siblings	t-test	SD*
19	Psychopathology; Prem. / Sibs	Chi-Square	SD*

20	ADD-H; Prem. / Siblings	Chi-Square	NS
21	ADD; Prem. / Siblings	Chi-Square	NS
22	Conduct / Op.; Prem. / Sibs	Chi-Square	SD*
23	Anxiety; Prem. / Sibs	Chi-Square	NS
24	Depression; Prem. / Sibs	Chi-Square	NS
Section II.	**Secondary Hypotheses:**		
25	FSIQ; VLBW / LBW / Siblings	Anova	SD*
26	VIQ; VLBW / LBW / Siblings	Anova	NS
27	PIQ; VLBW / LBW / Siblings	Anova	SD*
28	Reading; VLBW / LBW	Anova	SD*
29	Spelling; VLBW / LBW	Anova	SD*
30	Arithmetic; VLBW / LBW	Anova	SD*
31	Global LD; VLBW / LBW	Chi-Square	NS
32	Language LD; VLBW / LBW	Chi-Square	NS
33	Arithmetic LD; VLBW / LBW	Chi-Square	SD*
34	HRNB Comp.; VLBW/LBW/Sibs	Anova	SD*

* Denotes Significance at the .05 Level

With respect to the Primary research hypotheses, the cognitive performance of the Premature Group (n = 32) differed significantly from the Sibling Control Group (n = 8) for FSIQ (p = .009) and PIQ (p = .006), but not for VIQ (p = .055). Prematures scored lower than Siblings and with greater variation in subtest performance on the WISC-R. Prematures also differed significantly from Siblings on all three Kaufman (1979) WISC-R Factor scores including Verbal Comprehension (p = .036), Perceptual Organization (p = .066), and Freedom From Distractibility (p = .000). Significant correlations were also noted for birthweight and FSIQ (p = .012) as well as for PIQ (p = .003); but not VIQ (p = .080), for Prematures (n = 32).

Academically, the Premature Group scored lower than the Sibling Group on all three WRAT-R subtests with significant differences noted for the Reading (p = .011) and Arithmetic subtests (p = .046), but not for the Spelling subtest (p = .075). Children from the Premature Group (n = 32) differed significantly from Siblings (n = 8) with respect to special education placement (p = .004) as approximately 56% required special education intervention compared to the Sibling Group who did not require any special assistance (0%).

Birthweight of children in the Premature Group (n = 32) was associated with more impaired global (composite) scores on the HRNB-C. Differences in neuropsychological test scores on the HRNB-C were apparent for Prematures (n = 32) and Siblings (n = 8) including more indicators of neuropsychological brain dysfunction on global (composite scores) measures of the HRNB-C (p = .000). Differences in subtest performance was also noted for the two groups of children including the Category (p = .002), Speech Sounds Perception (p = .003), Seashore Rhythm (p = .001), Tactual Performance (p = .022), Finger Tapping (p = .017), and Grooved Pegboard Tests (p = .006). Differences between the two groups was also noted on composite scores for the Sensory-Perceptual Examination (p = .011) and Aphasia Screening Test (p = .000). Significant differences between the two groups of children were not noted for the Trail Making Test or Hand Dynamometer Test, however children from the Premature Group were observed to score lower than Sibling Controls. Interestingly, lower birthweight was not correlated with more impaired performance on the HRNB-C Composite scores (p = .824) for the Premature Group (n = 32).

A significant difference between the Prematures (n = 32) and Siblings (n = 8) was noted for Visual-motor integration (p = .000), with approximately 78% of the Prematures classified as having "abnormal" Bender-Gestalt Test performance, compared to 0% in the Sibling Group.

Differences between the two groups of children was also noted on the SIDAC psychopathology subtypes. A higher proportion of children with some degree of general psychopathology was also noted among the Prematures (n = 32; p = .000), compared to the Sibling Group (n = 8). Prematures differed significantly from the Sibling Group with respect to the proportions of children with a clinical rating of Conduct / Oppositional Disorder (p = .04), however, no significant differences between the groups was noted for Attention Deficit Disorder with Hyperactivity (p = .08), Attention Deficit Disorder (p = .09), Anxiety Disorder (p = .36) or Depression (p = .07). In all cases, the Premature Group (n = 32) demonstrated a higher proportion of children with specific subtypes of psychopathology compared to Siblings (n = 8).

Results of the Secondary research hypotheses comparing the performance of children within the Premature Group with Very Low Birthweight (VLBW, n = 12), Low Birthweight (LBW, n = 20), and the Sibling Group (n = 8), were also generally supported by the data.

The three groups of children (VLBW, LBW and Siblings) differed significantly from each other with respect to their cognitive performance on the WISC-R Full Scale IQ (p = .05) and Performance IQ (p = .02), but not for Verbal IQ (p = .06). It was further noted that children from the Sibling Group (n = 8) differed significantly (higher IQ scores) from the LBW subgroup (n = 20) of Prematures for Full Scale IQ, however, no significant difference was noted between the Siblings and the VLBW (n = 12) Prematures. A significant difference in Performance IQ was also noted between the VLBW subgroup (n = 12) and the Sibling Group (n = 8), but not within the Premature subgroups (VLBW vs. LBW). It was also noted that the VLBW subgroup displayed higher mean Full Scale IQ and Verbal IQ compared to the LBW subgroup. However, the VLBW subgroup was observed to score slightly lower than the LBW subgroup for Performance IQ. All Prematures displayed lower mean IQ scores when compared to Siblings.

Differences in academic achievement and for the three groups of children (VLBW, LBW, and Siblings) were also observed. Children from the three groups differed significantly from each other on the WRAT-R subtests including Reading (p = .001) and Spelling (p = .018), but not on the Arithmetic subtest (p = .153). A significant difference was noted in Reading scores of children in the Sibling Group (n = 8) and the LBW subgroup (n = 20), and between the LBW and VLBW (n = 12) subgroups. However, no significant difference in Reading scores was noted between the VLBW subgroup and the Sibling Group. Spelling scores differed significantly between the VLBW and LBW subgroups, however, no significant difference was noted in Spelling scores of the VLBW and LBW subgroups when compared to the Sibling Group.

Differences in proportions of Learning Disability subtypes using both WRAT-R subtest scores and WISC-R FSIQ criteria, were also observed for children within the Premature Group (VLBW, n = 12; LBW, n = 20). Children from the two groups did not differ significantly from each other with respect to the proportion of children classified as Global Learning Disabled (VLBW = 16.6%, LBW = 25%; p = .58) or Language Disabled (VLBW = 16.6%, LBW = 30%; p = .40). However, both subgroups of Prematures differed significantly from each other with respect to the proportion of children with a Learning Disability in Arithmetic (VLBW = 25%, LBW = 0%; p = .02). None of the children in the Sibling Control Group (n = 8) were classified as Learning Disabled in any category.

A significant difference in neuropsychological performance between the VLBW (n= 12), LBW (n = 20), and Sibling (n = 8) groups, was noted for HRNB-C Composite scores (p = .01). It was further noted that the composite performance of children in the Sibling Group (n = 8) differed significantly from the LBW subgroup. The Siblings also differed significantly from the VLBW subgroup on composite HRNB-C scores. However, no significant differences were noted between the VLBW and LBW subgroups.

Additional or ancillary results pertaining to the performance of both the Premature and Sibling groups, subgroups of Prematures, and the entire sample of children, is noted in Section III of this chapter.

Section I. Primary Research Hypotheses Results

Cognitive Functioning Hypotheses Results (WISC-R)

Hypothesis 1: Premature Birthweight vs. IQ

Hypothesis 1 stated that there will be significant relationships between birthweight and Verbal, Performance, and Full Scale IQ scores on the WISC-R for the Premature Group. Correlation coefficients (Pearson r) for all subjects in the Premature Group (n = 32) are noted in Table 8 below:

Table 8. Correlation Coefficients. Birthweight / IQ: Prematures

Variables	Correlation (r)	P = (* .05; ** .01)
Birthweight / FSIQ	-.33	.012**
Birthweight / VIQ	-.22	.080
Birthweight / PIQ	-.42	.003**

As noted in Table 8 above, Birthweight correlates negatively with Full Scale IQ for children in the Premature Group with $r = -0.33$ ($p < 0.05$ significance). Birthweight of children in the Premature Group also correlates negatively with Verbal IQ ($r = -0.22$), however, the result was not significant at the .05 level. The correlation coefficient for birthweight and Performance IQ score of children was also negative ($r = -0.42$), and was significant at the $p < .05$ level.

This hypothesis was partially supported by the data indicating that there is a significant relationship between birthweigth and Full Scale IQ scores as well as Performance IQ scores, but not Verbal IQ scores, on the WISC-R for children from the Premature Group. Furthermore, the value obtained in the correlation coefficients for Full Scale IQ scores and Performance IQ scores indicated that higher birthweight values were associated with lower IQ scores on the WISC-R for the Premature Group.

Hypothesis 2: IQ: Premature vs. Control Group

Hypothesis 2 stated that there will be significant differences in mean Verbal, Performance, and Full Scale IQ scores between children in the Premature Group and the Sibling Control Group. The mean WISC-R IQ scores of children in the Premature Group (n = 32) and the Sibling Control Group (n = 8) are noted in Table 9 below:

Table 9. t-Tests, WISC-R IQ, Prematures / Siblings

WISC-R Subtests	Prematures (m; sd)	Siblings (m; sd)
FSIQ	95.3; 14.0	107.6; 9.4
VIQ	94.9; 15.7	103.3; 8.4
PIQ	96.8; 13.6	111.6; 11.0

As noted in Table 9 above, there were significant differences between the mean Full Scale IQ scores ($t = 2.96$; $p = .009$) and Performance IQ scores ($t = 3.28$; $p = .006$) of children in the Premature and Sibling Control Groups. However, the difference of Verbal IQ scores of children between the two groups were not statistically significant ($t = 2.03$; $p = .055$). This hypothesis was partially supported by the data indicating that only the mean Performance and Full Scale IQ scores for children in the Premature Group differed significantly from the mean IQ scores of children from the Sibling Control Group, whereas Verbal IQ scores did not differ significantly between these two groups. In general, the Premature Group performance was lower than Siblings on the WISC-R.

Hypothesis 3: Kaufman Factors: Prematures vs. Control Group

Hypothesis 3 stated that there will be significant differences in mean Verbal Comprehension, Perceptual Organization, and Freedom From Distractibility Factor scores on the WISC-R for children between the Premature and the Sibling Control Group. The mean WISC-R Subtest Factor scores (Kaufman, 1979) of children between the Premature (n = 32) and the Sibling Control Group (n = 8) are noted in Table 10 below:

Table 10. t-Tests. WISC-R Factor Scores. Prematures / Siblings

WISC-R Factors	Prematures (m; sd)		Siblings (m; sd)	
Verbal Comp. Factor	9.1;	3.1	10.7;	1.3
Perceptual Org. Factor	9.3;	2.7	11.6;	1.6
Freedom From Dist.	8.5;	2.1	10.5;	0.9

As noted in Table 10 above, a comparison of the mean Verbal Comprehension Factor scores ($t = 2.21$; $p = .036$), and the Perceptual Organizational Factor ($t = 3.12$; $p = .006$), and the Freedom From Distractibility Factor ($t = 4.01$; $p = .000$), of children in both groups, showed significant differences at the .05 significance level. This hypothesis was supported by the data as significant differences were noted when comparing the mean Verbal Comprehension, Perceptual Organization, and Freedom From Distractibility Factor scores of the WISC-R for children from the Premature Group and children from the Sibling Control Group.

Academic Functioning Hypotheses Results (WRAT-R)

Hypothesis 4: WRAT-R Subtests vs Premature Group

Hypothesis 4 stated that there will be significant relationship between WRAT-R Reading, Spelling, and Arithmetic Test Scores and birthweight of children from the Premature Group (n = 32). The correlation coefficients (Pearson r) for all three subtest scores of the WRAT-R and birthweight of children appear in Table 11 below:.

Table 11. Correlation Coefficients, Prematures / WRAT-R Subtests

WRAT-R Subtests	Correlation (r)	P = (* .05; ** .01)
Reading / Prematures	-.36	.011**
Spelling / Prematures	-.23	.075
Arithmetic / Prematures	-.27	.046*

As noted in Table 11 above, birthweight of children correlates negatively with their Reading subtest scores (r = -0.35) at the .05 significance level. The correlation coefficient for birthweight and the Spelling subtest score was r = -0.23, however, it was not significant at the .05 level. The correlation coefficient for the Arithmetic subtest score and birthweight of children was r = -0.27 and was significant at the .05 level. This hypothesis was partially supported by the data indicating that there is a significant relationship between WRAT-R Reading and Arithmetic subtest scores and birthweight of children from the Premature Group, but no significant relationship was identified for the Spelling subtest for Prematures.

Hypothesis 5: WRAT-R Subtests: Prematures vs. Control Group

Hypothesis 5 stated that there will be significant differences in mean WRAT-R Reading, Spelling, and Arithmetic subtest scores for children from the Premature and Sibling Control Groups. The means of the WRAT-R subtest scores of children in the Premature (n = 32) and Sibling Group (n = 8), appear in Table 12 below:

Table 12. t-Tests. WRAT-R Subtests. Prematures / Siblings

WRAT-R Subtests	Prematures (m; sd)	Siblings (m; sd)
Reading	89.3; 14.8	102.6; 10.8
Spelling	87.9; 12.3	95.5; 15.8
Arithmetic	87.6; 10.8	95.1; 12.4

As noted in Table 12 above, the difference of the mean Reading subtest scores of both groups was significant at the .05 level ($t = 2.87$; $p = .012$), but not for the Spelling ($t = 1.26$; $p = .238$), or Arithmetic subtests ($t = 1.57$; $p = .148$). This hypothesis was therefore partially supported by the data as significant differences were noted when comparing the mean WRAT-R Reading scores for children from the Premature Group and children from the Sibling Control Group. However, significant differences between the two groups of children were not noted for the Spelling and Arithmetic Subtests of the WRAT-R.

Hypothesis 6: Special Education: Prematures vs. Control Group

Hypothesis 6 stated that there will be significant differences in the proportion of children placed in special education settings between the Premature and Sibling Control Groups. Approximately 56% of the children in the Premature Group were classified as being in special education whereas none (0%) of the children in the Sibling Group were in special education (Chi Square = 8.18; $df = 1$; $p = .004$). This hypothesis was supported by the data indicating a significant difference in the proportion of children in special education settings from the Premature Group compared to the Sibling Control Group.

Neuropsychological Functioning Hypotheses Results (HRNB-C)

Hypothesis 7: Birthweight vs. HRNB Composite: Prematures

Hypothesis 7 stated that there will be a significant relationship between birthweight and composite scores on the HRNB-C for children from the Premature Group (n = 32). The correlation coefficient (Pearson r = .44) between these two variables was significant at the .05 level (p = .002). This hypothesis was supported by the data as a significant relationship was noted between birthweight and HRNB-C composite scores for the Premature Group of children, indicating that higher (more impaired) composite scores were associated with Premature birthweight.

A comparison of the differences in performance (t-tests) between the Premature Group (n = 32) and the Sibling Control Group (n = 8) for HRNB-C Composite Scores, Category Test error scores, Trail Making Test, Speech Sounds Perception Test, and Seashore Rhythm Test , appears in Table 13 (Hypotheses 8 - 11) below:

Table 13. t-Tests. HRNB-C Subtests. Prematures / Siblings

HRNB-C Subtests	Prematures (m; sd)	Siblings (m; sd)	t value	P value
HRNB-C Composite	29.4; 18.5	9.1; 4.8	-5.47	.000*
Category	55.1; 21.7	35.3;11.7	-3.49	.002*
Trail Making T Part A	92.8; 16.1	101.6; 9.6	1.95	.066
Trail Making T Part B	98.8; 16.7	103.0; 7.7	1.05	.303
Speech Sounds P T	98.4; 15.2	108.6; 3.6	3.16	.003*
Seashore Rhythm T	101.3; 14.1	115.0; 7.6	3.67	.001*

* Denotes p = < .05

Hypothesis 8: HRNB Composite: Prematures vs. Control Group

Hypothesis 8 stated that there will be a significant difference in mean composite HRNB-C scores for children from the Premature and Sibling Control Group. As noted in Table 13 above, there is a significant difference in the composite scores of children between the two groups at the .05 level (t = -5.47; p = .000). This hypothesis was supported by the data indicating that the

Premature Group and the Sibling Control Group differed very significantly from each other with respect to their composite score performance on the HRNB-C. Children from the Premature Group had significantly higher (more impaired performance) scores with respect to their composite score performance on the HRNB-C.

Hypothesis 9: Category Test: Prematures vs. Control Group

Hypothesis 9 stated that there will be a significant difference in mean HRNB-C Category Test error scores for children from the Premature and children from the Sibling Control Group. As noted in Table 13 above, there is a significant difference in the mean error scores of children between the two groups at the .05 level ($t = -3.49$; $p = .002$). This hypothesis was supported by the data indicating that the Premature Group and the Sibling Control Group differed very significantly from each other with respect to their test performance on the HRNB-C Category Test. Children from the Premature Group had significantly higher (more impaired performance) error scores on the Category Test of the HRNB-C.

Hypothesis 10: Trail Making Test: Prematures vs. Control Group

Hypothesis 10 stated that there will be a significant difference in mean standard scores for Part A and Part B of the HRNB-C Trail Making Test for children from the Premature and Sibling Control Group. As noted in Table 13 above, there is no significant difference in the mean standard scores on the TMT Part A for children from the Premature Group and Sibling Control Group at the .05 level ($t = 1.95$; $p = .066$). Differences in standard scores on the TMT Part B for children from the Premature and Sibling Control Group was also not significant at the .05 level ($t = 1.05$; $p = .303$). This hypothesis was not supported by the data indicating that the Premature Group and the Sibling Control Group did not differ significantly from each other with respect to their mean test performance on either Part A or Part B of the HRNB-C Trail Making Test. Generally speaking, children from the Premature Group scored lower than the Sibling Group on both Part A and B of the TMT.

Hypothesis 11: SSPT / SRT: Prematures vs. Control Group

Hypothesis 11 stated that there will be a significant difference in mean HRNB-C Speech Sounds Perception Test and Seashore Rhythm Test standard scores for children from the Premature and Sibling Control Group. As noted in Table 13 above, the difference in mean SSPT standard scores for children from the Premature and Sibling Control Group was significant at the .05 level ($t = 3.16$; $p = .003$). The difference in mean SRT standard scores for children from the Premature and Sibling Control Group was also significant at the .05 level ($t = 3.67$; $p = .001$). This hypothesis was supported by the data indicating that the Premature Group and the Sibling Control Group differed very significantly from each other with respect to their mean test performance on the HRNB-C Speech Sounds Perception Test and the HRNB-C Seashore Rhythm Test. Children from the Premature Group scored significantly lower than the Sibling Group on both the SSPT and SRT of the HRNB-C.

Hypothesis 12: TPT Dominant Hand: Prematures vs. Sibling Control Group

Hypothesis 12 stated that there will be a significant difference in mean HRNB-C Tactual Performance Test of children between the Premature Group ($n = 32$) and Sibling Control Group ($n = 8$). Table 14 summarizes the performance of both groups on the TPT.

Table 14. t-Tests. Tactual Performance Test. Prematures / Siblings

TPT Subtests	Prematures (m; sd)	Siblings (m; sd)	t value	P value
TPT Dominant H	99.7; 18.5	109.4; 9.2	2.09	.048*
TPT Nondom. H	101.2; 20.9	112.0; 5.4	2.57	.014*
TPT Both H	101.9; 20.7	111.4; 4.0	2.40	.022*
TPT Memory	97.2; 10.7	99.0;11.2	0.40	.695
TPT Localization	96.8; 11.8	104.6; 5.9	2.61	.016*

* Denotes p = < .05

As noted in Table 14 above, significant differences in mean scores were noted between children in the two groups in all comparisons except the TPT Memory subtest. The difference in the mean standard scores of children between the two groups on the Dominant Hand Trial of the TPT for children from the Premature Group and the Sibling Control Group, was significant at the .05 level (t = 2.09; p = .048). The difference in mean standard scores of children between the two groups on the Nondominant Hand Trial, was significant at the .05 level (t = 2.57; p = .014). The difference in mean standard scores of children between the two groups on the Both Hand Trial was significant at the .05 level (t = 2.40; p = .022). The difference in mean standard scores of children between the two groups on the Memory Test however, was not significant at the .05 level (t = .40; p = .695). The difference in mean standard scores of children between the two groups was significant at the .05 level (t = 2.61; p = .016).

This hypothesis was partially supported by the data indicating that the Premature Group and the Sibling Control Group differed significantly from each other with respect to their overall performance on most subtests of the HRNB-C Tactual Performance Test including Dominant Hand Trial, Nondominant Hand Trial, Both Hand Trial, and Localization Subtest performance. This hypothesis was not supported by the data on the TPT Memory Subtest as significant differences between the two groups was not noted. In most cases, the performance of the Premature Group lower than the Sibling Group on the TPT.

A comparison of the differences in performance (t-tests) of children between the Premature Group (n = 32) and the Sibling Control Group (n = 8) for the HRNB-C Hand Dynamometer Test, Finger Tapping Test, and Grooved Pegboard Test appears in Table 15 (Hypotheses 13 - 15) below:

Table 15. t-Tests. HRNB-C Subtests. Prematures / Siblings

HRNB-C Subtests	Prematures (m; sd)	Siblings (m; sd)	t value	P value
HDT Dominant H	107.4; 12.4	112.0; 14.3	0.84	.423
HDT Nondom. H	109.9; 12.2	109.7; 15.9	-0.03	.978
FTT Dominant H	106.2; 17.5	121.5; 13.3	2.72	.017*
FTT Nondom. H	103.7; 17.9	114.8; 18.5	1.66	.123
GPT Dominant H	96.9; 10.4	107.6; 6.0	3.10	.006*
GPT Nondom. H	96.2; 10.8	99.8; 8.0	0.46	.652

* Denotes p = < .05

Hypothesis 13: Hand Dynamometer Test: Prematures vs. Control Group

Hypothesis 13 stated that there will be a significant difference in mean HRNB-C Hand Dynamometer Test standard scores of children between the Premature and Sibling Control Group. As noted in Table 15 above, a comparison of the mean standard scores between the two groups on the Dominant Hand Trial of the HDT, was not significant at the .05 level ($t = 0.84$; $p = .423$). The difference in mean standard scores of children between the two groups on the Nondominant Hand Trial of the HDT, was also not significant at the .05 level ($t = -0.03$; $p = .978$). This hypothesis was not supported by the data indicating that the Premature Group and the Sibling Control Group did not differ significantly from each other with respect to their test performance on the HRNB-C Hand Dynamometer Test. Children from the Premature Group performed lower than the Sibling Group for the Dominant Hand Trial, however, their performance was generally similar for the Nondominant Hand Trial of the HDT.

Hypothesis 14: Finger Tapping Test: Prematures vs. Control Group

Hypothesis 14 stated that there will be a significant difference in mean HRNB-C Finger Tapping Test standard scores of children between the Premature Group and the Sibling Control Group. As noted in Table 15 above, a comparison of the mean standard scores of children between the two groups on the Dominant Hand Trial of the FTT, was significant at the .05 level ($t = 2.72$; $p = .017$). The difference in mean standard scores of children between the two groups on the Nondominant Hand Trial of the FTT, was not significant at the .05 level ($t = 1.66$; $p = .123$). This hypothesis was partially supported by the data indicating that the Premature Group and the Sibling Control Group differed significantly from each other with respect to their Dominant Hand Trial test performance but not their Nondominant Hand Trial performance on the HRNB-C Finger Tapping Test. Children from the Premature Group performed lower than the Sibling Group in general on both trials of the FTT.

Hypothesis 15: Grooved Pegboard Test: Prematures vs. Control Group

Hypothesis 15 stated that there will be a significant difference in mean HRNB-C Grooved Pegboard Test standard scores of children between the Premature and Sibling Control Group. As noted in Table 15 above, a comparison of the differences in mean standard scores of children between the two groups on the Dominant Hand Trial, was significant at the .05 level (t = 3.10; p = .006). The difference in mean standard scores between the two groups on the Nondominant Hand Trial however, was not significant at the .05 level (t = 0.46; p = .652). This hypothesis was partially supported by the data indicating that the Premature Group and the Sibling Control Group differed significantly from each other with respect to their Dominant Hand Trial test performance but not their Nondominant Hand Trial performance on the HRNB-C Grooved Pegboard Test. In general, children from the Premature Group scored lower than the Sibling Group on both trials of the GPT.

Hypothesis 16: Aphasia Screening Test: Prematures vs. Control Group

Hypothesis 16 stated that there will be a significant difference in mean composite HRNB-C Aphasia Screening Test scores for children from the Premature Group (m = 0.87; sd = 0.60) and the Sibling Control Group (m = 0.14; sd = 0.16). A comparison of the mean composite scores of children between the two groups was significant at the .05 level (t = -6.16; p = .000). This hypothesis was supported by the data indicating that the Premature Group and the Sibling Control Group differed very significantly from each other with respect to their composite test performance on the HRNB-C Aphasia Screening Test. Children from the Premature Group scored significantly higher (more impaired performance) than the Sibling Group on the Aphasia Screening Test composite score.

Hypothesis 17: Sensory-Perceptual Exam: Prematures vs. Control Group

Hypothesis 17 stated that there will be a significant difference in mean composite HRNB-C Sensory Perceptual Exam scores for children from the Premature Group (m = 0.95; sd = 0.69) and the Sibling Control Group (m = 0.27; sd = 0.28). A comparison of the mean composite scores of children between the two groups was significant at the .05 level ($t = -4.28$; $p = .011$). This hypothesis was supported by the data indicating that the Premature Group and the Sibling Control Group differed significantly from each other with respect to their composite test performance on the HRNB-C Sensory Perceptual Examination. Children from the Premature Group scored significantly higher (more impaired performance) than the Sibling Group on the Sensory-Perceptual Examination composite score.

Visual-Motor Integration Hypothesis Results (Bender Gestalt)

Hypothesis 18: Bender Test: Prematures vs. Control Group

Hypothesis 18 stated that there will be a significant difference in mean Bender Gestalt Test standard scores for children from the Premature Group ($m = 71.3$; $sd = 22.9$) and the Sibling Control Group ($m = 100.1$; $sd = 3.4$). A comparison of the mean standard scores between the two groups was significant at the .05 level ($t = 6.83$; $p = .000$). This hypothesis was supported by the data indicating that the Premature Group and the Sibling Control Group differed very significantly from each other with respect to their test performance on the Bender Gestalt Test. Children from the Premature Group scored significantly lower (more impaired performance) than the Sibling Group on the Bender-Gestalt Test.

Psychopathology/Behavioral Hypotheses Results (SIDAC)

Table 16 below (Hypotheses 19 - 24) compares the proportion (Chi-square) of children from the Premature Group (n = 32) and the Sibling Control Group (n = 8) with a clinical rating of global psychopathology and/or psychopathology subtypes on the SIDAC:

Table 16. Chi-square. SIDAC Subtype (%). Prematures / Siblings

SIDAC Type	Prematures(n=32) (%)	Siblings (n=8) (%)
Psychopathology	87.5	15.6
ADD-H	46.9	12.5
ADD	28.1	0.0
CD/OP	37.5	0.0
Anxiety	28.1	12.5
Depression	31.3	0.0

Hypothesis 19: Psychopathology: Prematures vs. Control Group

Hypothesis 19 stated that there will be significant differences in the proportions of children with a clinical rating of psychopathology on the SIDAC between the Premature and the Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of the two groups was significantly different at the .05 level (Chi-Square = 15.74; df = 1; p = .000). This hypothesis was supported by the data as significant differences were noted in the proportions of children with clinical rating of psychopathology from the Premature Group (87.5%) when compared to the Sibling Control Group (15.6%) on the SIDAC.

Hypothesis 20: ADD-H: Prematures vs. Control Group

Hypothesis 20 stated that there will be significant differences in the proportions of children with a clinical rating of Attention Deficit Disorder with Hyperactivity (ADD-H) on the SIDAC between the Premature and Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of children rated as ADD-H between the two groups, was not significantly different at the .05 level (Chi-Square = 3.15; df = 1; p = .08). This hypothesis was not supported by the data indicating that the Premature Group (46.9%) and the Sibling Control Group (12.5%) did not differ significantly from each other with respect to clinical rating of Attention Deficit Disorder with Hyperactivity on the SIDAC.

Hypothesis 21: ADD: Prematures vs. Control Group

Hypothesis 21 stated that there will be significant differences in the proportions of children with a clinical rating of Attention Deficit Disorder (ADD) on the SIDAC between the Premature and Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of children rated ADD between the two groups was not significantly different at the .05 level (Chi-Square = 2.90; df = 1; p = .09). This hypothesis was not supported by the data indicating that the Premature Group (28.1%) and the Sibling Control Group (0%) did not differ significantly from each other with respect to clinical rating of Attention Deficit Disorder on the SIDAC.

Hypothesis 22: Conduct/Opposition: Prematures vs. Control Group

Hypothesis 22 stated that there will be significant differences in the proportions of children with a clinical rating of Conduct / Oppositional Disorder on the SIDAC between the Premature and the Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of children rated as Conduct Disorder / Oppositional Disorder, between the two groups, was significantly different at the .05 level (Chi-Square = 4.29; df = 1; p = .04). This hypothesis was supported by the data indicating that children from the Premature Group (37.5%) differed significantly from the Sibling Control Group (0%) for clinical rating of Conduct / Oppositional Disorder on the SIDAC.

Hypothesis 23: Anxiety: Prematures vs. Control Group

Hypothesis 23 stated that there will be significant differences in the proportions of children with a clinical rating of Anxiety Disorder on the SIDAC between the Premature and Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of children rated with Anxiety Disorder between the two groups was not significantly different at the .05 level (Chi-Square = 0.83; df = 1; p = 0.36). This hypothesis was not supported by the data indicating that no significant relationship exists between children from the Premature Group (28.1%) and the Sibling Control Group (12.5%) for the clinical rating of Anxiety Disorder on the SIDAC.

Hypothesis 24: Depression: Prematures vs. Control Group

Hypothesis 24 stated that there will be significant differences in the proportions of children with a clinical rating of Depression on the SIDAC between the Premature and Sibling Control Group. As noted in Table 16 above, a comparison of the proportions of children rated with Depression between the two groups was not significantly different at the .05 level (Chi-Square = 3.33; df = 1; p = 0.07). This hypothesis was not supported by the data indicating that a significant relationship does not exist between children from the Premature Group (31.3%) and the Sibling Control Group (0%) for the clinical rating of Depression.

Section II. Secondary Research Hypotheses Results

Cognitive Functioning Differences Results. VLBW / LBW Prematures & Sibling Controls

The cognitive performance (WISC-R) within the Premature group of children with Very Low Birthweight (VLBW; n = 12) and Low Birthweight (LBW; n = 20) was compared with the performance of the children in the Sibling Control Group (n = 8) using one-way ANOVA and Multiple Comparisons as noted below in Table 17:

Table 17. ANOVA. WISC-R. VLBW / LBW Prematures / Siblings

WISC-R	F Ratio	df	P value
FSIQ	3.23	2	.05*
Verbal IQ	3.00	2	.06
Performance IQ	4.20	2	.02*

* Denotes p = or < .05

Hypothesis 25: FSIQ: VLBW / LBW / Siblings

Hypothesis 25 stated that there will be significant differences in mean Full Scale I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group. Mean WISC-R IQ scores of children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and the Sibling Group (n = 8), are noted in Table 18 below:

Table 18. WISC-R IQ. VLBW / LBW Prematures & Siblings

WISC-R Scales	VLBW (m; sd)	LBW(m; sd)	Siblings (m;sd)
FSIQ	97.1;12.5	92.8;16.1	107.6; 9.4
VIQ	100.3;13.4	90.3;17.1	103.3; 8.4
PIQ	94.3;13.4	96.7;15.4	111.8; 11.0

As noted in Table 17 above, one-way Analysis of Variance indicated significant differences in mean WISC-R Full Scale IQ scores of children in the three groups (F = 3.23; df = 2; p = 0.05). Multiple comparisons of the means of the three groups revealed a difference at the .05 significance level, between the mean Full Scale IQ scores of children in the Sibling Control Group and the LBW subgroup. However, no significant difference was noted between the mean Full Scale IQ of children in the VLBW subgroup and the Sibling Control Group. In addition, no significant difference was noted between the LBW and the VLBW subgroup. This hypothesis was supported by the data, indicating that the three groups differed significantly from each other with respect to their mean Full Scale IQ scores.

Hypothesis 26: VIQ: VLBW / LBW / Siblings

Hypothesis 26 stated that there will be significant differences in mean Verbal I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group. Mean WISC-R Verbal IQ scores of children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and the Sibling Group (n = 8), are noted in Table 18 above.

As noted in Table 17 above, one-way Analysis of Variance indicated no significant differences in mean Verbal IQ scores between children in the three groups (F = 3.00; df = 2; p = 0.06). Multiple comparisons were therefore not performed for the three groups. This hypothesis was not supported by the data, indicating no significant differences between the three groups with respect to their Verbal IQ scores.

Hypothesis 27: PIQ: VLBW / LBW / Siblings

Hypothesis 27 stated that there will be significant differences in mean Performance I.Q. scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and children from the Sibling Control Group. Mean WISC-R Performance IQ scores for children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and the Sibling Group (n = 8), are noted in Table 18 above.

As noted in Table 17 above, one-way Analysis of Variance indicated significant differences in mean Performance IQ scores between children in the three groups (F = 4.20; df = 2; p = 0.02). Multiple comparisons of the means of the three groups revealed a difference at the .05 significance level, between the mean Performance IQ of children in the Sibling Control Group and the LBW subgroup as well as the VLBW subgroup. However, no significant difference was noted between the mean Performance IQ scores of children in the VLBW subgroup and the LBW subgroup. This hypothesis was supported by the data, indicating that the three groups differed significantly from each other with respect to their Performance IQ scores.

Academic Functioning Differences Results, VLBW / LBW Prematures & Sibling Controls

Differences in academic performance (WRAT-R) of children within the Premature group with Very Low Birthweight (VLBW; n = 12) and Low Birthweight (LBW; n = 20), was compared with the Sibling Control Group (n = 8) using one-way ANOVA and Multiple Comparisons as noted below in Table 19. Comparative analysis was also conducted with respect to the proportions of children displaying various Learning Disability subtypes, based on their performance on the WRAT-R and the WISC-R.

Table 19. ANOVA, WRAT-R, VLBW / LBW Prematures / Siblings

WRAT-R	F Ratio	df	P value
Reading	7.96	2	.001*
Spelling	4.51	2	.018*
Arithmetic	1.98	2	.153

* Denotes p = < .05

Hypothesis 28: Reading: VLBW / LBW / Siblings

Hypothesis 28 stated that there will be significant differences in mean WRAT-R Reading scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and the Sibling Control Group. Mean differences in WRAT-R achievement scores for children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and Sibling Groups (n = 8), are noted in Table 20 below:

Table 20. WRAT-R, VLBW / LBW Prematures & Siblings

WRAT-R Scales	VLBW (m: sd)	LBW(m: sd)	Siblings (m:sd)
Reading	97.4;12.9	82.2; 15.5	102.6; 10.8
Spelling	94.3;10.1	82.0; 13.9	95.5; 15.8
Arithmetic	89.3;11.7	86.1; 11.1	95.1; 12.4

As noted in Table 19 above, one-way Analysis of Variance indicated significant differences in mean WRAT-R Reading scores between children in the three groups (F = 7.96; df = 2; p = 0.001). Multiple comparisons of the means of the three groups revealed a significant difference at the .05 level, between the mean Reading scores of children in the Sibling Control Group and the LBW subgroup. In addition, a significant difference was noted in the mean Reading scores of children between the LBW and VLBW subgroup. However, there was no significant difference in the mean Reading scores of children in the VLBW subgroup and the Sibling Control Group. This hypothesis was supported by the data, indicating that the three groups differed significantly from each other with respect to their mean scores on the WRAT-R Reading subtest.

Hypothesis 29: Spelling: VLBW / LBW / Siblings

Hypothesis 29 stated that there will be significant differences in mean WRAT-R Spelling scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and the Sibling Control Group. Mean WRAT-R Spelling achievement scores for children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and the Sibling Group (n = 8), are noted in Table 20 above.

As noted in Table 19 above, one-way Analysis of Variance indicated significant differences in mean WRAT-R Spelling scores between children in the three groups (F = 4.51; df = 2; p = 0.018). Multiple comparisons of the means of the three groups revealed a difference at the .05 significance level, in the mean Spelling scores of children between the VLBW subgroup and LBW subgroup. However, no significant differences were noted between the mean Reading scores of children in the VLBW and LBW subgroups when compared to the Sibling Control Group. This hypothesis was supported by the data, indicating that the three groups differed significantly from each other with respect to their mean WRAT-R Spelling subtest performance.

Hypothesis 30: Arithmetic: VLBW / LBW / Siblings

Hypothesis 30 stated that there will be significant differences in mean WRAT-R Arithmetic scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW), children with birthweights above 1500 grams (Low Birthweight or LBW), and the Sibling Control Group. Mean WRAT-R Arithmetic achievement scores for children with Very Low Birthweight (VLBW; n = 12), Low Birthweight (LBW; n = 20), and Sibling Group (n = 8), are noted in Table 20 above.

As noted in Table 19 above, one-way Analysis of Variance indicated no significant differences in mean WRAT-R Arithmetic scores between children in the three groups (F = 1.98; df = 2; p = 0.153). Multiple comparisons were therefore not performed for the three groups. This hypothesis was not supported by the data, indicating no significant differences between the three groups with respect to their mean WRAT-R Arithmetic subtest scores.

Table 21 below (Hypotheses 31 - 33) describes the proportions of children from the Premature Group with Very Low Birthweight (VLBW; n = 12) and Low Birthweight (LBW; n = 20) diagnosed with Global LD, Language LD, and Arithmetic LD, based on their performance on the WRAT-R subtests (standard scores < 80) and the WISC-R (FSIQ > 80):

Table 21. Chi-square, LD Subtype (%), VLBW / LBW Prematures

LD Subtype	VLBW (n=12) (%)	LBW (n=20) (%)
Global LD	16.6	25.0
Language LD	16.6	30.0
Arithmetic LD	25.0	0.0

Hypothesis 31: Global LD: VLBW vs. LBW Prematures

Hypothesis 31 stated that there will be significant differences in the proportions of children identified as Globally Learning Disabled (mean WRAT-R Reading, Spelling & Arithmetic standard scores <80 but Full Scale IQs >80) between the Premature Group with Very Low Birthweight (<1500 grams or VLBW) and Low Birthweight (>1500 but <2500 grams or LBW).

As noted in Table 21 above, a comparison of the proportions of children with Global LD using Chi-Square was not significantly different at the .05 level (Chi-Square = 0.31; df = 1; p = .58). This hypothesis was not supported by the data indicating that no significant differences exist between VLBW (16.6%) and LBW (25%) Prematures for Global Learning Disability rating.

Hypothesis 32: Language LD: VLBW vs. LBW Prematures

Hypothesis 32 stated that there will be significant differences in the proportions of children identified as Language Learning Disabled (mean WRAT-R Reading &Spelling standard scores <80 but Full Scale IQs >80) between the Premature Group with Very Low Birthweight (<1500 grams or VLBW), and Low Birthweight (>1500 but <2500 grams or LBW). As noted in Table 21 above, a comparison of the proportions of children with Language LD between the two groups was not significantly different at the .05 level (Chi-Square = 0.71; df = 1; p = 0.40). This hypothesis was not supported by the data indicating that no significant differences exist between VLBW (16.6%) and LBW (30%) Prematures identified as Language Learning Disabled.

Hypothesis 33: Math LD: VLBW vs. LBW Prematures

Hypothesis 33 stated that there will be significant differences in the proportions of children identified as Learning Disabled in Arithmetic (mean WRAT-R Arithmetic standard scores <80 but Full Scale IQs >80) between the Premature Group with Very Low Birthweight (<1500 grams or VLBW) and Low Birthweight (>1500 but <2500 grams or LBW). As noted in Table 21 above, a comparison of the proportions of children rated with Arithmetic LD between the two groups was significantly different at the .05 level (Chi-Square = 5.52; df = 1; p = 0.02). This hypothesis was supported by the data indicating statistical significance between VLBW (25%) and LBW (0%) Prematures identified as Learning Disabled in Arithmetic.

Neuropsychological Functioning Differences Results. VLBW / LBW Prematures & Sibling Controls

Differences in neuropsychological performance (HRNB-C Composite scores) within the Premature group of children for Very Low Birthweight (VLBW; n = 12) and Low Birthweight (LBW; n = 20), was compared with the performance of the Sibling Control Group (n = 8) using one-way ANOVA and Multiple Comparisons.

Hypothesis 34: HRNB-C Composite: VLBW / LBW / Siblings

Hypothesis 34 stated that there will be significant differences in mean HRNB-C Composite scores between children from the Premature Group with birthweights below 1500 grams (Very Low Birthweight or VLBW; n = 12; mean = 25.33), children with birthweights above 1500 grams (Low Birthweight or LBW; n = 20; mean = 31.8), and the Sibling Control Group (n = 8; mean = 9.12). One-way Analysis of Variance indicated significant differences in mean Composite scores between children in the three groups (F = 5.17; df = 2; p = 0.01). Multiple comparisons of the means of the three groups revealed a difference at the .05 level, in composite HRNB-C scores of children in the Sibling Control Group and the LBW. A significant difference in composite scores was also noted between the Siblings and the VLBW subgroup. However, no significant differences were noted between the LBW and the VLBW subgroup. This hypothesis was supported by the data, indicating that the three groups differed significantly from each other with respect to their mean HRNB-C Composite scores.

Section III. Additional Results

Supplemental Correlations. Premature Group

Supplemental Correlational analysis (Pearson r) was also conducted on selected variables related to the above hypotheses. A significant relationship was noted between birthweight of the Premature Group (n = 32) and Reading as well as Arithmetic subtest scores of the WRAT-R, but not the Spelling subtest. These results suggested that lower scores on these WRAT-R subtests were associated with birthweight of children from the Premature Group. A summary of correlation coefficients comparing the relationship between birthweight of the Premature Group (n = 32) and WISC-R as well as WRAT-R subtests is found in Table 22 below.

Table 22. Correlation Coefficients. Premature Birthweight (n=32) / WRAT-R

Variables	Correlation (r)	P = (* .05; ** .01)
Prematures / Reading	-.36	.01**
Prematures / Spelling	-.23	.07
Prematures / Arithmetic	.27	.046*

Several significant relationships were noted between birthweight and medical history as well as psychopathology exclusively for the Premature Group (n = 32). A significant relationship (Pearson r) was noted between Respiratory Distress Syndrome, frequently present in Prematures, and birthweight. An abnormal medical history was also strongly associated with birthweight of the Premature Group (Point-Biserial). Birthweight of the Prematures was not associated with Retrolental Fibroplasia, Cerebral Palsy, Seizures, Head Injury, Fetal Alcohol Syndrome, Delayed Language or Motor development, but was associated with High Fever (Point-Biserial). Birthweight of the Prematures was associated with the clinical manifestation of Attention Deficit Disorder with Hyperactivity (ADD-H), Attention Deficit Disorder (ADD), and Depression (Point-Biserial). A summary of the correlation coefficients comparing the birthweight of the Prematures (n = 32) with the above variables appears in Table 23 below.

Table 23. Correlation Coefficients. Birthweight / Medical History / Psychopathology (n=32)

Variables	Correlation	P = (* .05; ** .01)
Birthweight / RDS	.30	.02*
Birthweight / RLF	.11	.24
Birthweight / FAS	.16	.15
Birthweight / Cerebral Palsy	.11	.24
Birthweight / Seizures	.21	.09
Birthweight / Head Injury	.11	.23
Birthweight / High Fever	.47	.001**
Birthweight / Medical History	-.56	.000**
Birthweight / Delayed Language	-.19	.12
Birthweight / Delayed Motor	.14	.19
Birthweight / ADD	.26	.04*
Birthweight / ADD-H	.28	.04*
Birthweight / Depression	.28	.03*

Supplemental Correlations. Academic Performance

The relationship (Point-Biserial) between academic achievement scores and the presence or absence of an abnormal medical history was notably significant for only the Arithmetic subtest of the WRAT-R but not for the Spelling or Reading subtests. A summary of these values is noted in Table 24 below.

Table 24. Correlation Coefficients. WRAT-R / Medical History (n=40)

Variables	Correlation	P = (* .05; ** .01)
Reading / Medical History	.12	.21
Spelling / Medical History	-.04	.38
Arithmetic / Medical History	.40	.005**

The relationship (Pearson r) between academic achievement and selected global measures of neuropsychological performance was notably strong for Reading, Spelling and Arithmetic subtests and HRNB Composite scores indicating that higher or more impaired performance on the HRNB was associated with lower WRAT-R Reading, Spelling and Arithmetic scores. Higher (more impaired) HRNB Category error scores were associated with lower scores on WRAT-R Reading and Arithmetic subtests but not the Spelling subtest. A summary of these results is noted in Table 25 below.

Table 25. Correlation Coefficients. WRAT-R / HRNB Subtests (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Reading / HRNB Composite	-.53	.000**
Spelling / HRNB Composite	-.41	.004**
Arithmetic / HRNB Composite	-.56	.000**
Reading / HRNB Category	-.31	.02**
Spelling / HRNB Category	-.15	.17
Arithmetic / HRNB Category	-.37	.01**

The relationship (Point-Biserial r) between academic achievement and HRNB Aphasia Screening Test (AST) performance was evaluated as these clinical indicators of aphasia were only noted in the performance of children in the Premature Group. WRAT-R Reading test performance (lower scores) was associated with the presence of Constructional Dyspraxia, Dyscalculia, Spelling Dyspraxia and Dyslexia but not Dyspraxia, Right-Left Confusion, Dysgraphia or Dysnomia. Lower scores on the Spelling subtest of the WRAT-R was associated with Dyscalculia, Spelling Dyspraxia and Dyslexia, but not Constructional Dyspraxia, Dysgraphia, Dyspraxia, Right-Left Confusion or Dysnomia. Lower Arithmetic tests scores were associated with virtually all indicators of aphasia including Constructional Dyspraxia, Dyspraxia, Right-Left Confusion, Dysgraphia, Dyscalculia, Spelling Dyspraxia and Dyslexia, but not Dysnomia. A summary of the correlation coefficients (Point-Biserial r) for the Aphasia Screening Test performance and WRAT-R subtests is noted in Table 26 below.

Table 26. Correlation Coefficients, WRAT-R / Aphasia Screening (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Reading / Constr. Dyspraxia	-.32	.02*
Spelling / Constr. Dyspraxia	-.23	.07
Arithmetic / Constr. Dyspraxia	-.37	.009**
Reading / Dyspraxia	-.14	.19
Spelling / Dyspraxia	-.13	.19
Arithmetic / Dyspraxia	-.31	.02*
Reading / R-L Confusion	-.20	.10
Spelling / R-L Confusion	-.20	.10
Arithmetic / R-L Confusion	-.37	.01**
Reading / Dysgraphia	-.14	.19
Spelling / Dysgraphia	-.13	.19
Arithmetic / Dysgraphia	-.31	.02*
Reading / Dyscalculia	-.36	.01**
Spelling / Dyscalculia	-.37	.009**
Arithmetic / Dyscalculia	-.56	.000**
Reading / Dysnomia	-.11	.24
Spelling / Dysnomia	-.22	.08
Arithmetic / Dysnomia	-.02	.42
Reading / Sp. Dyspraxia	-.31	.02*
Spelling / Sp. Dyspraxia	-.28	.04*
Arithmetic / Sp. Dyspraxia	-.31	.02*
Reading / Dyslexia	-.71	.000**
Spelling / Dyslexia	-.64	.000**
Arithmetic / Dyslexia	-.39	.000**

The relationship (Point-Biserial r) between academic achievement and HRNB Sensory-Perceptual Test (SPE) performance was evaluated as impaired performance was only noted in children from the Premature Group. Lower scores on the WRAT-R Reading subtest were associated with errors on the Tactile Form Recognition and Fingertip Number Writing subtests of the SPE, but were not associated with performance on the Finger Agnosia or Imperception subtests. Lower scores on the Spelling subtest was not associated with any of these sensory-perceptual subtests. Lower scores on the Arithmetic subtest of the WRAT-R was associated with more impaired performance on the Finger Agnosia and Fingertip Number Writing subtests but not on the Tactile Form Recognition or the Imperception subtests of the SPE. A summary of the correlation coefficients (Point-Biserial r) relating to the above variables is noted in Table 27 below.

Table 27. Correlation Coefficients. WRAT-R / Sensory-Perceptual Exam (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Reading / Imperception	-.19	.12
Spelling / Imperception	-.06	.33
Arithmetic / Imperception	-.11	.24
Reading / Finger Agnosia	-.23	.06
Spelling / Finger Agnosia	-.07	.33
Arithmetic / Finger Agnosia	-.34	.01**
Reading / Tactile Form Recog.	-.30	.03*
Spelling / Tactile Form Recog.	-.10	.27
Arithmetic / Tactile Form Recog.	-.06	.34
Reading / Fingertip # Writing	-.37	.009**
Spelling / Fingertip # Writing	-.24	.06
Arithmetic / Fingertip # Writing	-.25	.05*

Supplemental Correlations. Developmental Status

The relationship (Point-Biserial r) between academic achievement and delayed language (> 18 months) or delayed motor (> 18 months) performance was also evaluated as these indicators of delayed development were only noted in the history of children from the Premature Group. Lower Reading subtest scores on the WRAT-R were associated with children who displayed a history of delayed language but not delayed motor development. Lower scores on the Spelling subtest were also only associated with children who displayed a history of delayed language but not delayed motor development. Lower Arithmetic scores were associated with children with a history of both delayed language and motor development. A summary of the correlation coefficients (Point-Biserial r) for these variables is noted in Table 28 below.

Table 28. Correlation Coefficients. Delayed Language / Motor. WRAT-R (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Delayed Language / Reading	-.29	.03*
Delayed Language / Spelling	-.26	.05*
Delayed Language / Arithmetic	-.47	.001**
Delayed Motor / Reading	-.05	.36
Delayed Motor / Spelling	-.02	.44
Delayed Motor / Arithmetic	-.29	.03*

The relationship between intellectual ability and delayed language or delayed motor performance was also evaluated as these indicators of delayed development were only noted in the history of children from the Premature Group. Lower scores on WISC-R Verbal, Performance and Full Scale scores were associated with children having a history of delayed language development (> 18 months) but not delayed motor development (> 18 months). A summary of the correlation coefficients (Point-Biserial r) for these variables is noted in Table 29 below.

Table 29. Correlation Coefficients. Delayed Language / Motor. WISC-R (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Delayed Language / VIQ	-.63	.000**
Delayed Language / PIQ	-.32	.02*
Delayed Language / FSIQ	-.57	.000**
Delayed Motor / VIQ	-.20	.10
Delayed Motor / PIQ	-.09	.28
Delayed Motor / FSIQ	-.18	.13

The relationship (Point-Biserial r) between neuropsychological performance and delayed language or delayed motor performance was also evaluated as these indicators of delayed development were only noted in the history of children from the Premature Group. Higher (more impaired) HRNB composite scores and higher (more impaired) HRNB Category error scores were strongly associated with children who displayed a history of delayed language (> 18 months) and motor development (> 18 months). The presence of Constructional Dyspraxia, an indicator of aphasia often associated with right hemisphere parietal lobe dysfunction, was associated with children who displayed a history of delayed motor development but not delayed language development (Tetrachoric r). A summary of the correlation coefficients for these variables is noted in Table 30 below.

Table 30. Correlation Coefficients. Delayed Language / Motor. HRNB (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Del. Lang. / HRNB Composite	.56	.000**
Del. Lang. / HRNB Category	.43	.003**
Del. Motor / HRNB Composite	.38	.006**
Del. Motor / HRNB Category	.31	.02*
Del. Lang. / Constr. Dyspraxia	.19	.12
Del. Motor / Constr. Dyspraxia	.25	.05*

Supplemental Correlations. Visual-Motor Integration

The relationship (Pearson r) between visual-motor integration and selected variables was evaluated as poor scores on the Bender-Gestalt Test were only noted among children from the Premature Group (lower scores on the Bender were strongly associated with lower birthweight values, a history of delayed language and motor development, lower scores for the WRAT-R Reading and Arithmetic subtests, but not on the WRAT-R Spelling subtest). Poor Bender scores were also strongly associated with lower Verbal, Performance and Full Scale IQ scores on the WISC-R. Lower scores on the Bender were also associated with children who were currently enrolled in special education settings (none in the Sibling Control Group). Impaired Bender performance was also associated with higher (more impaired) performance on the HRNB composite and Category Test scores as well as for Constructional Dyspraxia (Point-Biserial r), an index of right hemispheric parietal lobe integrity. Bender scores were also associated with poor performance on Part B of the Trail Making Test but not on Part A. Lower Bender scores were also associated with clinical ratings for Attention Deficit Disorder with Hyperactivity but not Attention Deficit Disorder without Hyperactivity (Point-

Biserial r). Lower Bender test performance as also highly associated (Point-Biserial r) with children having abnormalities in basic personality functioning on the SIDAC (almost exclusively within the Premature Group). A summary of the correlation coefficients for these variables is noted in Table 31 below.

Table 31. Correlation Coefficients. Bender-Gestalt / Selected Variables (n=40)

Variables	Correlation (r)	P = (* .05; ** .01)
Bender / Birthweight	.40	.004**
Bender / VIQ	.44	.002**
Bender / PIQ	.68	.000**
Bender / FSIQ	.62	.000**
Bender / Reading	.29	.03*
Bender / Spelling	.24	.06
Bender / Arithmetic	.38	.008**
Bender / Sp. Educ.	-.34	.01**
Bender / TMT A	.16	.16
Bender / TMT B	.32	.02*
Bender / HRNB Category	.58	.000**
Bender / HRNB Composite	-.70	.000**
Bender / Cons. Dyspraxia	-.49	.001**
Bender / Delayed Language	-.36	.01**
Bender / Delayed Motor	-.48	.001**
Bender / ADD	.01	.48
Bender / ADD-H	-.28	.03*
Bender / Abnormal Personality	.50	.000*

Supplemental Group Comparisons. Parental History

Additional analysis was also conducted on selected variables in order to further investigate differences noted between the Premature Group and the Sibling Group. Differences in parental background including education level and occupational level was investigated (t-test). It was noted that the education level of the fathers from the Premature Group (Table 4 above) compared to the Sibling Group (Table 6 above) did not differ significantly. However, the educational level of the mothers of both groups of children (Table 4 above) did differ significantly as mothers from the Sibling Group (Table 6 above) reported a slightly higher level of education . The occupational status of fathers from the Premature Group (Table 3 above) differed significantly from fathers of children from the Sibling Group (Table 5 above) as most were employed in a variety of service occupations including farming while most fathers of the Sibling Group reported slightly higher occupational status (technical and/or sales). The occupational status of mothers from both groups also differed significantly from each other as most mothers from the Premature Group (Table 3 above) reported that they were employed in jobs with slightly lower status (service occupations) compared to most mothers of children from the Sibling Group (Table 5 above) who reported working in the technical and/or sales areas, similar to their husbands. A summary of the means and t-test results for these variables is noted in Table 32 below.

Table 32. t-Tests. Parental History. Prematures / Siblings

Parental Hist.	Prematures (m; sd)	Siblings (m; sd)	t value	P value
Father Education	1.71; 0.95	2.00; 0.92	0.76	.46
Mother Education	1.96; 0.74	2.62; 0.51	2.92	.01*
Father Occupation	4.46; 1.75	2.75; 1.16	-3.33	.00*
Mother Occupation	4.50; 1.86	2.75; 1.38	-2.95	.01*

* Denotes p = < .05

During the clinical interview, approximately 22% of the fathers of children in the Premature Group reported a personal or family history of learning problems compared to approximately 25% of the fathers from the Sibling Group (25%), indicating that both groups of fathers shared a similar history. A family history of learning problems was not reported by mothers of the Sibling Group (0%) but was reported in approximately 22% of the mothers of children in the Premature Group, indicating that these groups of mothers may have been different.

Supplemental Group Comparisons. Clinical LD Diagnosis

Both groups of children were also compared using a clinical diagnostic method of determining the presence or absence of Learning Disability in the Reading, Spelling and Arithmetic areas. This diagnosis was applied using pattern analysis, IQ scores and discrepancies, standard score cut off markers and general clinical and educational history in a similar manner to established rules for clinical practise. Children were then classified into subtypes of LD based on the above criteria and compared across the Premature Group and the Sibling Control Group (Frequencies). The results indicate that none (0%) of the children from the Sibling Control Group (n = 8) were classified as Reading Disabled while approximately 53% of the Premature Group (n = 32) were classified as Reading Disabled based on the above criteria. With respect to a clinical rating of Spelling Disability subtype, approximately 63% of the Premature Group and 25% of the Sibling Control group were classified as LD for Spelling. The diagnostic (clinical) rating for Arithmetic Disability was noted in approximately 59% of the Premature Group but only 13% of the Sibling Control Group, based on the above clinical criteria. A summary of the percentage of children with a clinically derived diagnosis of LD subtype (Frequencies) is noted in Table 33 below.

Table 33. % Clinical Diagnosis of LD. Prematures (n=32) / Siblings (n=8)

LD Subtype	Prematures (%)	Siblings (%)
Reading Disability	53	0
Spelling Disability	63	25
Arithmetic Disability	59	13

Supplemental Group Comparisons. Aphasia Screening Tests

Neuropsychological performance of the Premature Group and the Sibling Control Group was further evaluated by comparing their relative performance (%) on the Aphasia Screening Test (AST), since these subtests are often performed poorly by Learning Disabled children with known neuropsychological deficits. With respect to the clinical presence or absence of Constructional Dyspraxia, none of the children in the Sibling Control Group (0%) demonstrated this pathognomonic sign compared to approximately 87.5% of children from the Premature Group who did. Spelling Dyspraxia was observed in approximately 59% of children in the Premature Group compared to only 13% of children from the Sibling Control Group. Dysgraphia, another pathognomonic sign of aphasic symptomatology, was demonstrated in approximately 28% of the Prematures only (0% for Siblings). Right-Left

Confusion was demonstrated in approximately 40% of the Prematures compared to 0% from the Sibling Group. Dyslexia on the AST was demonstrated in approximately 56% of the Premature Group compared to 0% from the Sibling Group. Dyscalculia was noted in approximately 69% of the Prematures compared to 37% for the Siblings. Dysnomia was demonstrated in approximately 50% of the Premature Group compared to 25% of the Sibling Group. A summary of these values (%) for both groups is noted in Table 34 below.

Table 34. % Aphasia Screening. Prematures (n=32)/Siblings (n=8)

AST Variables	Prematures (%)	Siblings (%)
Constructional Dyspraxia	87	0
Spelling Dyspraxia	59	13
Dysgraphia	28	0
R-L Confusion	40	0
Dyscalculia	69	37
Dyslexia	56	0
Dysnomia	50	25

Supplemental Group Comparisons. Sensory-Perceptual Exam

Neuropsychological performance of the Premature Group and the Sibling Control Group was further evaluated by comparing their relative performance (%) on the Sensory-Perceptual Examination (SPE), since these subtests are often performed poorly by Learning Disabled children with known neuropsychological deficits. With respect to the total number of Imperception errors on the Sensory-Perceptual Examination, approximately 41% children from the Premature Group were noted to display demonstrated abnormal performance (presence of pathognomonic signs) compared to none (0%) of the children in the Sibling Group. Similar results were noted for Finger Agnosia as none of the Sibling Control Group children (0%) demonstrated this sign while approximately 56% of children from the Premature Group demonstrated this sign Children from the Premature Group also demonstrated more errors on the Fingertip Number Writing subtest (63%) compared to Siblings who only demonstrated errors in 13% of the time. On the Tactile Form Recognition subtest of the SPE, both groups of children made errors (68% for Prematures; 62% for

Siblings). A summary of these values (%) for both groups is noted in Table 35 below.

Table 35. % Sensory-Perceptual Exam. Prematures (n=32)/Siblings (n=8)

SPE Variables	Prematures (%)	Siblings (%)
Imperception Errors	51	0
Finger Agnosia	56	0
Fingertip # Writing Errors	63	13
Tactile Form Recognition	68	62

Supplemental Group Comparisons. WISC-R Subtests

Differences in intellectual ability for Prematures (n = 32) and Siblings (n = 8) were also investigated through an analysis of subtest performance on the WISC-R since statistically significant results were noted for the global IQ scores for both groups. Generally speaking, children from the Premature Group did not differ significantly from the Sibling Control Group on their WISC-R Verbal subtest performance even though their overall subtest scores were clinically lower than scores for the same subtests for the Sibling Control Group. However, children from the Premature Group differed significantly from children in the Sibling Control Group on all remaining WISC-R Performance subtests as their overall performance was considerably lower than the performance of the Sibling Control Group. The most significant differences between the two groups were noted for the Object Assembly, Coding and Mazes subtests where subtest performance differed by almost a full standard deviation. A summary of the means and t-tests for both groups and these variables is noted in Table 36 below.

Table 36. t-Tests. WISC-R Subtests. Prematures (n=32) / Siblings (n=8)

WISC-R Subtest	Prematures (m; sd)	Siblings (m; sd)	t value	P value
Verbal Scale:				
Information	8.4; 2.9	10.3; 2.0	1.69	.11
Similarities	9.5; 2.7	11.6; 1.2	1.68	.11
Arithmetic	8.3; 2.9	10.1; 1.16	1.69	.11
Vocabulary	9.1; 3.6	10.5; 1.6	1.68	.10
Comprehension	9.5; 3.0	11.5; 2.5	1.93	.07
Digit Span	7.8; 2.6	9.5; 2.4	1.69	.11
Performance Scale:				
Picture Completion	10.9; 3.2	11.3; 1.5	0.40	.69
Picture Arrangement	9.3; 3.5	11.4; 1.9	2.27	.03*
Block Design	8.5; 3.5	11.8; 3.8	2.21	.05*
Object Assembly	8.7; 2.9	12.4; 1.8	4.61	.00*
Coding	9.2; 2.7	11.8; 1.8	3.18	.00*
Mazes	9.0; 2.4	11.0; 1.0	3.50	.00*

* Denotes p = < .05

CHAPTER VI

DISCUSSION

Results of any neuropsychological study with children are best understood within a theoretical framework of a developmental model of child neuropsychological functioning. Until recently, models of adult neuropsychological functioning had to be modified or downsized to make them conform to the rigorous demands imposed by developmental research variables involved in the study of children. It has been demonstrated in the literature review, that there are vast differences in normal brain development and functioning between children and adults. These differences are even more apparent when impairment and/or dysfunction of the brain occurs in children as more global versus "localized" deficits are noted with perhaps more enduring outcomes when compared to adults since the "trajectory" of normal development may be altered to a significant degree and therefore cause more dysfunction throughout an individual's lifespan. In addition, impairment and/or dysfunction of various components of the central nervous system may also cause secondary "effects" when those centers are required to provide a different or altered function later in development. These features can readily be seen among children who have experienced considerable medical problems at birth including prematurity. Medical research has clearly demonstrated the more overt sequelae of prematurity while little research has been conducted on more subtle neurodevelopmental disorders including Learning Disabilities. This may be due to the fact that one cannot die from a Learning Disability and therefore it may not be an important concern or a topic worth researching in medicine. However, since Learning Disabilities represent the largest group of disorders known to occur in children and the most frequent reason for referral to most professionals in virtually every clinical pediatric field, the importance of research within this field is unquestionably clear. Furthermore, comprehensive research investigating more subtle sequelae of subgroups of children based on their high-risk status at birth is needed in order to keep pace with early identification and intervention strategies designed to help children particularly in the fields of education and psychology. The literature review suggests that this field is in its infancy particularly with respect to the more powerful investigative techniques and neuropsychological assessment procedures available today that can better measure brain-behavior relationships throughout an individual's lifespan.

The literature review indicated that children with premature birthweight have consistently demonstrated a higher incidence of Learning Disability when compared to their normal birthweight counterparts. This early research has however, only demonstrated more global patterns of Learning Disability while more recent research with this population has focused on reading disabilities but paid little attention to other subtypes. Early and current research has also concentrated on younger children with relatively known medical complications since the research was based on samples of outpatient groups. These children may therefore have more obvious deficits and may be evidencing more learning deficits simply due to their higher risk status. The current study chose to sample a group of older volunteer and their Siblings as it was felt that these children may be more representative of the larger "population" of Prematures including those with relatively few problems. This group was also chosen as the author was interested in surveying a group of children who may have more subtle dysfunction that likely contributes to the development of LD and its subtypes. A Sibling Control group was used primarily to try to control for SES factors which often account for the lion's share of variability between groups used in previous studies.

The major focus of the current study was to investigate Learning Disabilities among a sample of older children with premature birth histories using a neuropsychological perspective and including an evaluation of the neuro-cognitive, academic, psychomotor and psychopathology dimensions, and comparing their performances with a group of normal birthweight Siblings acting as controls. An assumption was made that this group of premature children would likely display a variety of deficits in learning, cognition, neuropsychological function and psychopathology compared to Siblings with normal birthweights due to more subtle neurodevelopmental deficits that resulted from some type of early trauma and/or dysfunction to the developing brain. A review of the research indicated that neurodevelopmental deficits are often manifest in children with premature birth histories primarily due to the plethora of medical complications associated with prematurity as well as iatrogenic effects related to the treatment of Prematures while in the neonatal intensive care unit. It was therefore hypothesized that children form the Premature Group would likely display lower IQ and more variation between VIQ/PIQ, more indicators of a Learning Disability including certain subtypes of LD, more indicators of brain dysfunction on the HRNB, more indicators of visual-motor integration and more indicators of psychopathology and/or attentional deficits when compared to a sample of Siblings acting as controls (Sibling Group). It was further hypothesized that the Premature group would display more specific patterns of Learning Disability, particularly in mathematics, including more variation in Verbal or Performance I.Q., with perhaps lower Performance IQ, more impaired performance on the HRNB particularly for complex nonverbal skills as well as sensory-perpceptual function, and more indicators of psychopathology including attentional deficits, when compared to their Siblings with normal birth histories. In addition, it was hypothesized that the very low birthweight Prematures (VLBW = <1500 grams) would likely display more deficits on all the above variables when compared to Prematures with slightly higher birthweight (LBW = 1500- 2500 grams).

The literature review included a discussion of Learning Disability research including subtype analysis with respect to premature birth outcome. The results appear to be quite consistent with previous observations and suggest that Learning Disabilities likely arising from more subtle brain dysfunction, are frequently noted among Prematures well into the middle childhood period and into early adolescence. Furthermore, the pattern of Learning Disability appears to follow conventional research findings suggesting some dysfunction of the linguistic functions including reading and arithmetic but not spelling. A unique pattern of arithmetic deficits was noted for the Prematures with lower versus higher birthweight when compared to other non-premature LD groups who appear to have more linguistic deficits. Significantly lower Full Scale and Performance IQ ratings were also noted among the Premature group suggesting the possibility of early destruction and/or dysfunction of cerebral white matter associated with right cerebral hemisphere disorders as noted by Rourke in his description of "Nonverbal Learning Disabilities" (1982; 1987; 1988). Significantly more impaired performance on broad measures of neuropsychological integrity were also noted for the Premature Group in relation to the Sibling Group indicating the presence of more subtle brain dysfunction within this group of children despite improvements in medical technology and service delivery to this new and unique group of children. A relationship was also noted between lower birthweight and lower intellectual ability, lower achievement scores, more impaired neuropsychological performance, more impaired visual-motor integration and more indicators of psychopathology. These results provide compelling evidence that children born with premature birthweight appear to be at high risk for a host of neuropsychological and/or developmental disorders including psychopathology not only in their early childhood period as noted by prior studies, but well into their middle childhood and early adolescent years. The results of this study also addressed theoretical and applied implications including the importance of neuropsychological assessment procedures for children with premature birth history. The comprehensive format of neuropsychological assessment techniques allows for the evaluation of more subtle deficits that are often not captured by traditional psycho-educational procedures. Having more specific and sensitive assessment results available would not only allow for more comprehensive and accurate diagnosis, but would aid in the construction of better and more appropriate remediation programming.

In analyzing the results of the current research, it became increasingly apparent that the neuropsychological performance of children from the Premature Group was very similar to a subgroup of children described by other researchers including Rourke. In addition, it was noted that the current group of Prematures illustrated many of the features of "nonverbal Learning Disability" described by Rourke (1982; 1987). In fact, Rourke's developmental model of neuropsychological functions in children provides an excellent framework for the discussion of the results of the current study which largely supports its theoretical paradigm.

Nonverbal Learning Disabilities (NLD)

Rourke (1987; 1988), has postulated a neurodevelopmental model of central processing functions and dysfunctions in children based on theoretical principles outlined by Goldberg & Costa (1981). Rourke indicates that any complete model of neuropsychological functioning in children should account for the following: (a) the full spectrum of children's perceptual, learning, mnestic, and other cognitive abilities and disabilities and (b) the three principal axes of concern in human brain-behavior relationships including the progression from lower to higher centers, from posterior regions of the cerebrum to the anterior regions, and the right hemisphere to left hemisphere progression. In other words, a model that simply explains a child's Learning Disability in reading for example, is grossly inadequate with respect to (a) above.

Rourke's early formulation of the NLD model (1982), was aimed at determining the interrelationships between the development of the brain as well as the development of the individual's approach to the material to be learned. Rourke recognized the fact that his early model had limited applicability since it took into consideration only the relative salience of the right versus left hemispheral system contributions to central processing and adaptive functioning. In other words, it did not provide an explanation of the full range of neurodevelopmental phenomena or more general brain-behavior relationships. Nevertheless, this early version of the NLD model was an important contribution to developmental neuropsychology since it evolved from Rourke's own developmental research with children as opposed to an attempt to "downscale" existing adult models of neurcpsychological function.

In the Rourke (1982) "Right-Left" model, it was suggested that this subtype of Learning Disability could be identified in children who were suffering from some type of disordered functioning of systems within the right cerebral hemisphere, or from some lack of access to such systems. In the Rourke (1987) model, focus is extended to include differences and interactions between white and grey matter in the brain. Rourke (1987; 1988) has termed his Nonverbal Learning Disability model (NLD) as the "Right-Left, Down-Up, Back-Front" Model (p. 295), primarily due to its emphasis on the three dimensions and progressions in neurodevelopment noted above. The model emphasizes the relative salience of right and left hemispheral systems during the ontogenetic course of cognitive development as well as developmental progression of learning at various levels of ontogenetic development. In doing so, Rourke has formulated a model that encompasses a relatively broad range of neuropsychological dimensions of human development and their ramifications in aspects of personal, academic, and social functioning.

Rourke (1982; 1987; 1989) postulated that early trauma to the developing brain often leads to a variety of developmental deficits which according to his theoretical model of child neuropsychological functioning, will be due to significant destruction or disturbance of function of white matter or long myelinated fibres in the brain. This destruction or dysfunction of white matter would likely occur for commissural fibres such as the corpus callosum interconnecting similar regions of both the right and left hemispheres, association fibres radiating from posterior to anterior regions and interconnecting cortical regions of the same cerebral hemisphere, and projection fibres projecting from "top" to "bottom" and connecting the diencephalon to the cerebral hemispheres, the brain stem and the spinal cord. Rourke indicates that all of these fibres can be destroyed or rendered dysfunctional by various sorts of neurological diseases or early birth trauma. He states that this pattern of destruction is frequently noted in the history and assessment findings of children with early head trauma particularly with respect to the shearing effect of acceleration-deceleration injuries, children requiring intensive radiotherapy for lukemia, perinatal cerebal palsy, poorly treated hydrocephalus, and in children with significant tissue removal particularly from the right cerebral hemisphere. He concluded that a variety of "nonverbal" deficits are manifested in these children primarily due to the general or diffuse destruction of white matter particularly within the right cerebral hemisphere since it contains a higher ratio of white matter to grey matter than the left hemisphere (Goldberg & Costa, 1981; Rourke, 1982; 1987, 1988). He also concludes that increased destruction of white matter fibers (relative to total brain mass) leads to increased manifestations of the "Nonverbal Learning Disability" syndrome (NLD), characterized by deficient performances in visual-spatial-organizational abilities, complex psychomotor and tactile-perceptual skills (usually more marked on the left side of the body), and conceptual / problem-solving abilities. He also postulates that the particular type of white matter that is lesioned, removed or dysfunctional and at which stage of development it is lesioned, removed or rendered dysfunctional has an important bearing on the NLD syndrome. In addition, Rourke concludes that since the white matter contained in the right cerebral hemisphere is crucial for the development and maintenance of specific functions early in life, including intermodal integration particularly of novel information processing, that destruction or permanent disruption of right hemisphere white matter would lead to the manifestation of NLD. This pattern of destruction would also be expected to generate a permanent handicap to the acquisition of new descriptive systems at any developmental stage and therefore contribute to many other associated features of the NLD syndrome noted earlier.

Rourke's extensive research with Learning Disabled children over the past 20 years has resulted in the identification of certain subtypes of LD children (Rourke, 1975; 1985; 1991; Rourke & Finlayson, 1978; Rourke & Strang, 1978; 1983). Rourke's subtypes were initially identified by performance on tests of word recognition, spelling and arithmetic performance on an academic achievement test (WRAT). Since 1971, in addition to identifying other subtypes, as noted in the literature review, Rourke concentrated on two particular subtypes of Learning Disabled children which he termed Group R-S and Group A. Group R-S consisted of children who displayed relatively poor psycholinguistic skills in conjunction with very well-developed abilities in visual-spatial-organizational, tactile-perceptual, psychomotor, and nonverbal skills and abilities. Group A children exhibited the opposite pattern of significant difficulties in visual-spatial-organizational, tactile-perceptual, psychomotor, and nonverbal problem-solving skills and abilities, but significant strengths in psycholinguistic skills such as rote verbal learning, regular phoneme-grapheme matching, amount of verbal output, and verbal classification. Rourke indicated that Group A children experienced their major academic learning difficulties in mechanical arithmetic while showing advanced levels of word-recognition and spelling, while Group R-S children showed very poor reading and spelling skills but significantly better, though still impaired, mechanical arithmetic performance. While studying both groups, Rourke concluded that Group A children illustrated a "nonverbal Learning Disability" pattern similar in theory to the the subgroup first identified by Myklebust (1975).

Rourke (1987; 1988) describes the Nonverbal Learning Disability (NLD) syndrome in terms of primary or secondary neuropsychological "assets" versus "deficits" displayed by children with the following pattern of performance. Primary neuropsychological assets displayed by children with NLD include intact simple motoric skills particularly at older age levels, intact auditory-perceptual skills, and intact ability to learn rote material particularly in the auditory modality including repetitious motoric acts, some aspects of speech, and well practiced skills such as handwriting that eventually develop from early stages of developmental "lag" to an average or above average level in middle to late childhood. Secondary neuropsychological assets include intact rote verbal memory for material that is readily coded, excellent phonemic hearing, segmentation, blending, repetition, and well developed receptive language skills. A high volume of speech output including a large store of rote verbal material and verbal associations are also noted as secondary verbal assets for these children, with more skills noted with advancing years. Following initial problems with visual-motor skills and with much practice in using a pencil, academic assets of these children include good graphomotor skills for words and excellent single-word decoding skills. Single word spelling via dictation also tends to develop to an average or even above average level with most common misspellings of the phonetically accurate variety. Verbatim memory for oral and written material could also develop to high levels in the middle to late elementary school years.

Primary neuropsychological deficits illustrated by children with NLD including bilateral tactile-perceptual deficits, usually more marked on the left side of the body, becoming less prominent with advancing age. Impaired discrimination and recognition of visual detail and visual relationships are also noted with significant deficits in visual-spatial-organizational ability, tending to increase with age. Bilateral psychomotor coordination deficits are prominent with more marked deficiency on the left side of the body, and except for well-practiced skills such as handwriting, tend to increase in severity as these children grow older. Primary deficits among children with NLD also include impaired ability to deal with novel material including poor age-appropriate accommodation to, and marked tendency toward over-assimilation of, novel events as they mature. Secondary neuropsychological deficits include poor attention to tactile and visual input with a tendency toward more impairment in performance with increasing age, except for over-learned tasks such as printed text, where the performance may not deteriorate with age. Deployment of selective and sustained attention appears to be much better for simple, repetitive verbal material (particularly if delivered auditoraly) when compared to complex, novel or nonverbal material (particularly if the mode of presentation is visual or haptic). Rourke adds that the difference between attentional deployment capacities for these two sets of material also tends to increase with age. Included in the list of secondary neuropsychological deficits illustrated by NLD children, are deficits in exploratory behavior as Rourke indicates that these children engage in little physical exploration of any kind even for objects within easy reach that could be explored visually or through tactile means. He notes a tendency toward more sedentary and physically limited modes of functioning for these children with increasing age.

Since NLD children often manifest a host of complex neuro-behavioral, academic and social deficits, Rourke summarizes these as tertiary neuropsychological deficits including poor memory for tactile and visual input with increases noted with age, aside from over-learned tasks such as spoken natural language. Memory for nonverbal material presented either auditoraly, visually or through tactile modalities, is poor if such material cannot be readily coded in a verbal fashion. Relatively poor memory of complex, meaningful, and /or novel verbal and nonverbal material is frequently observed among children with NLD. The difference between good to excellent memory for rote material and impaired memory for complex material not readily coded in a verbal fashion, tends to also increase with age. Marked deficits are also observed in concept-formation, problem solving, strategy generation and hypothesis testing including appreciation for information feedback, particularly if the information is novel or complex, are common features of tertiary neuropsychological deficits displayed by NLD children. Significant difficulties in dealing with cause-effect relationships or appreciation of incongruities including age-appropriate sensitivity to humor, are also observed among children with NLD. These deficits are most noticeable when formal operational thought becomes a requirement including late childhood or early adolescence, and increase markedly with advancing years as the gap between performance on rote or overlearned tasks versus novel tasks, increases.

Verbal neuropsychological deficits of children with NLD include mildly deficient oral-motor praxis, little or no speech prosody, combined with much verbosity of a repetitive or rote nature. Praphasic errors are often of the phonological rather than semantic variety. Poor psycholinguistic pragmatics such as "cocktail party speech", and a reliance upon language as a principal means for social relating, information gathering, and relief from anxiety, are also noted in NLD children, according to Rourke (1987). He further states that all of these features, except for oral-motor praxis, tend to become more prominent with increasing age.

Academic deficits illustrated by children with NLD include considerable difficulty with printing and cursive script particularly in the early school years, with a better prognosis noted for handwriting with increasing age and following much practise. Reading comprehension tends to be much poorer than single word reading (decoding), with deficits noted particularly in the comprehension of novel material, increasing with age. Significant deficits are observed in mechanical arithmetic when compared to proficiency in single word reading and spelling skills with the gap between these two groups of skills widening with increasing age. Rourke further notes that the mechanical arithmetic performance of children with NLD rarely exceeds the Grade 5 level, and that mathematical reasoning as opposed to over-learned arithmetic operations, remains poorly developed for these children. Persistent difficulties are also observed in other academic subjects involving problem solving and complex concept-formation such as physics, with observable gaps noted between these subjects and other subjects demanding more rote or over-learned skills, increasing with age.

In addition to these neuropsychological and academic deficits, Rourke (1987) describes a unique set of socio-emotional and/or adaptive deficits among children with NLD. He indicates that these children have extreme difficulty in adapting to novel and otherwise complex situations since these situations require organization, analysis, and synthesis of material. He notes that these children demonstrate and over-reliance on prosaic, or rote behaviors in such situations with increases in these deficits noted as children mature. Significant deficits are also noted in social perception, social judgement, and social interaction skills with increased deficit noted with advancing age. A marked tendency toward social withdrawal or even social isolation is apparent with advancing years. The early childhood histories of children with NLD often indicate acting-out behaviors or conduct disorder but with increasing age, these children become at risk for more "internalized" forms of psychopathology. Indicators of excessive anxiety, depression, and associated internalized forms of socio-emotional disturbance tend to increase with age, according to Rourke. These children are also frequently perceived as hyperactive during their early childhood but with advancing years, tend to become more normal in their activity level and eventually hypoactive.

In summarizing the essential features of the NLD syndrome, it is important to note that virtually all the potential "assets" displayed by these children center in their capacity to process auditory information, despite the fact that these children often also manifest weaknesses in a variety of auditory domains in their early developmental period and are frequently described by others as "hard of hearing". These children also tend to have a discernible delay in the acquisition of speech as well as in other developmental milestones and therefore, it is not unusual for these children to be referred for an evaluation early in their development, only to be "mis-diagnosed" as "immature". Indeed, parents are often relieved with this prognosis as they also notice a steady progression in the rate of speech production for their children with increasing age, regardless of the fact that they may not be making normal progress in other developmental milestones such as locomotion and manipulative skills, that contribute to the NLD syndrome. In the end, although these children appear to develop a high rate of speech production, they still appear to be behind their peers with respect to "functional" language skills later in life. Reading comprehension is typically poor but single word-recognition and spelling are frequently adequate. Arithmetic skills are quite poor as are virtually all aspects of nonverbal reasoning skills including problem solving and mental flexibility. Tactile perception and complex psychomotor performance is often impaired bilaterally with more deficits noted for the left side of the body. Social-emotional deficits including poor social judgement, lack of prosody in conjunction with a high rate of speech, poor adaptability to novel situations, poor nonverbal communication are manifest in NLD children. He has also concluded that young children with NLD remain essentially sedentary and do not explore their environment through vision or locomotion but rather through verbal means or by receiving answers to questions, possibly leading to different patterns of cognitive development and the manifestation of NLD. Rourke has also suggested that NLD children move from developmental presentation of "hyperactivity" to "normoactive" behavior and finally to a "hypoactive response style" with increasing withdrawal, isolation and feelings of loneliness Rourke has therefore argued for the "developmental presentation" of the NLD syndrome since the early clinical manifestation of deficits for the syndrome may occur in very different form compared to later clinical presentation (1988).

Unlike adult models, the uniqueness of Rourke's most current model (1987; 1988) is its applicability to child neuropsychology as it was designed to address the dynamic factors involved in the development of both normal and disabled learning. Its focus on the importance of novelty and familiarity within the act of learning and the child's attempts at adaptation throughout the course of development , is particularly valuable. The central theme of this model involves a discussion of intermodal and intramodal integration of information and the relative superiority of right versus left hemispheral systems in the various stages of cognitive development. This model is particularly important for the field of Learning Disabilities as it provides a sound neuropsychological bases from which a discussion of subtypes can emerge. Since this model was developed specifically within the context of child neuropsychological research, it has direct applicability to disorders of the developing brain. The current study was conducted with an aim toward investigating the neuropsychological aspects of learning disorders that are frequently manifest in children with premature birth history. The results of the study appear to support the general principles outlined by Rourke's model with respect to the cognitive, academic, neuropsychological, psychomotor, and behavioral performance of older children with premature birth history when compared to a group of normal birthweight Siblings.

Premature Birthweight and Cognitive Function

Research evaluating premature birth outcome has consistently demonstrated a variety of cognitive deficits arising from the high-risk status of this group of children (Caputo & Mandell, 1970; Wiener, 1962). These cognitive deficits are associated with a variety of developmental and learning deficits frequently noted among children with premature birth histories well into their middle childhood years and on into adolescence. The relationship between premature birth and subsequent cognitive and neurodevelopmental deficits was clearly demonstrated by a series of early studies both in the United Kingdom (Douglas, 1956; 1960; Douglas & Gear, 1976), and later replicated by studies conducted in the United States (Wiener, Rider, Oppel, Fischer, & Harper, 1965; Wiener, 1968; Wiener, Rider, Oppel & Harper, 1968). More recent studies have also demonstrated this relationship in terms of generalized central nervous system damage and/or dysfunction resulting from perinatal complications associated with premature birth (Commey & Fitzhardinge, 1976; Nickel, Bennett & Lamson, 1982; Pfeiffer, Herrernan & Pfeiffer, 1985).

Early research on premature birth outcome focused primarily on differences in intelligence, noting lower IQ scores among Prematures. Research conducted in the late 1960's noted no significant differences between Prematures and normal-birthweight children when corrected gestational ages were used and very low birthweight Prematures were excluded from the sample (Churchill, 1965; Drillien, 1961; Willerman & Churchill, 1967). More recent studies have attempted to define the samples being studied more precisely and have noted more generalized or global intellectual deficits including mental handicap among surviving Prematures (Ahman, Lazarra, & Dykes, 1980; Gaiter, 1982; Grigoroiu-Serbanescu, 1984). These findings are also quite consistent with neuropsychological investigations that have concluded global or generalized impairment and/or dysfunction of the cerebral hemispheres (Hynd & Willis, 1988; Novick & Arnold, 1988). These findings are entirely consistent with neuroanatomical and neuro-behavioral models of brain function for children as representing a distinctly different pattern of performance when compared to the traditional "localization" models of adult brain functioning (Hynd & Obrzut, 1981b; Hynd & Willis, 1988; Rourke, 1982; 1985; 1987; 1991). In other words, early damage to the developing brain appears to have more pervasive effects on future cognitive development. The importance of evaluating more subtle deficits in cognitive functioning among Prematures has been highlighted and a variety of studies have been conducted recently as these deficits are often implicated in children with Learning Disabilities.

Results of the current study suggested a significant relationship between birthweight, Full Scale IQ, and Performance IQ (but not Verbal IQ) on the WISC-R for the Premature subjects. As expected, birthweight and IQ was not correlated among the Siblings, and it was concluded that the relationship between birthweight and Full Scale and Performance IQ and was strongest among the Prematures and therefore quite consistent with observations made by prior research. It was further noted that the Premature Group differed significantly from the Sibling Group for Full Scale and Performance IQ, with the Prematures scoring lower with respect to their mean performance on the WISC-R. This finding was also noted to be quite consistent with prior observations and suggests that children with low birthweight histories appear to have lower cognitive ability scores in general (and particularly for PIQ) when compared to their normal-birthweight counterparts, and in some cases even their own Siblings.

When compared to prior studies evaluating the cognitive performance of lower (VLBW) versus higher (LBW) birthweight children with premature birth history, in comparison to Siblings, results of the current study were somewhat inconsistent. On the one hand, Full Scale IQ scores of children with LBW or Low Birthweight (1500 - 2500 grams), were statistically different (lower) when compared to Siblings with normal birthweight, consistent with prior findings. On the other hand, Full Scale IQ scores of children with VLBW or Very Low Birthweight (<1500) included in the current study, were not noted to be statistically different from their Siblings as their overall mean Full Scale IQ scores (VLBW) were slightly higher than the LBW subgroup (but not statistically different from each other). This unusual finding may reflect an artifact related to small sample size as well as the inclusion of some children who were clearly "outliers" or represented atypically higher IQ scores compared to the general "population" of VLBW children who are frequently noted to have more significant problems (lower IQ scores) in virtually all aspects of neurodevelopmental functioning. These results may also represent subtle differences in sample selection as all Prematures involved in the current study were "non-referred" volunteers as opposed to children who were being followed up via hospital studies where the subjects are more likely to have encountered adverse perinatal "events" which may predispose them to later developmental deficits.

Further with respect to LBW / VLBW differences in Performance IQ, compared to Siblings, it was noted that LBW and VLBW Prematures differed significantly from Siblings for their mean PIQ scores. However, PIQ scores of the LBW versus VLBW subgroups of Prematures did not differ significantly from each other even though the mean PIQ scores were slightly lower for VLBW Prematures compared to LBW Prematures. These results are consistent when compared to prior studies that compare overall PIQ scores for Prematures. However, some inconsistencies are noted as VLBW Prematures scored only slightly lower (not statistically significant) than the LBW subgroup when in fact, children with VLBW are frequently noted to score lower on cognitive tests compared to children with LBW. The theoretical assumption here is that VLBW Prematures are more likely to have adverse medical histories leading to more developmental vulnerability as a group based on their smaller size and more fragile status as these children necessarily have lower gestational ages combined with both a higher morbidity and mortality rate.

More recent studies have clearly demonstrated this connection as it relates to neurobehavioral outcome for VLBW vs. LBW Prematures, indicating a strong relationship between lower birthweight and lower academic achievement, with the poorest performance associated with VLBW Prematures, compared to normal controls (Waber, McCormick, & Workman-Daniels, 1993). This research concluded that the increased risk factors for children with prematurity, reflect CNS injury from associated complications and/or the insult referable to premature birth itself. In other words, neurologically significant complications associated with prematurity can affect subsequent cognitive development. However, prematurity itself may also heighten risk. The inconsistency in results noted for the current study may therefore be due to small sample size resulting in a restricted range of observations or a small VLBW sample (n = 12) that was not truly representative of the broader "population" of VLBW children. On the other hand, the above results may also serve to illustrate that IQ scores alone may not be sensitive enough to more subtle neurodevelopmental deficits when compared to scores reflecting more direct neuropsychological processes. This can be clearly illustrated by noting the composite neuropsychological performance of LBW versus VLBW Prematures as both groups of Prematures differed significantly (more impaired functioning) from Siblings who were clearly within normal limits with respect to global brain dysfunction. The importance of including neuropsychological tests as part of a more comprehensive assessment system is underscored by these results as more useful information can be gained that may provide vital clues for the diagnostic and treatment process.

Unlike the significant findings noted for the above global subscales of the WISC-R, Verbal IQ scores were not associated with lower birthweight values for Siblings or Prematures. Statistically significant differences in Verbal IQ were also not observed when comparing Prematures to Siblings, or in comparing LBW Prematures to VLBW Prematures, even though the actual mean scores for Prematures were lower than those noted for Siblings. Significant differences were noted however, on the remaining two Kaufman (1979) Verbal Comprehension and Freedom From Distractibility Factors which indicates that these subscales may be more sensitive and therefore more useful to include in a test battery designed for children with Premature birth history.

These results suggest therefore that the global differences noted in Full Scale or Performance IQ for the Premature Group compared to the Sibling Group were largely due to differences in Performance IQ but not Verbal IQ. Additional support for differences in perceptual-motor or nonverbal problem solving skills among the two groups of children was further noted as the factor scores on the WISC-R Perceptual Organization (Kaufman, 1979) for the Premature Group differed significantly (lower mean scores) from those obtained for the Sibling Group. Supplemental comparisons conducted for the WISC-R subtests also yielded highly significant differences between the Premature and Sibling Groups in five of the six subtests comprising the Performance Scale. However, no differences were identified for the two groups on any of the Verbal Scale subtests. In any case, since the Premature Group tended to perform at a lower level than their normal birthweight counterparts, and since lower birthweight values strongly associated with more impaired performance on the

HRNB-C, it seems likely that children born with premature birth histories appear to have more global and/or performance-based deficits in intellectual ability, possibly linked with increased levels of central nervous system damage and/or dysfunction. Variations or decreases in Performance IQ are often associated with central nervous system damage or dysfunction since many of these subtests tap speed of information processing, visual-gestalt skills, inductive and deductive reasoning, perceptual speed and other aspects of "fluid" intellectual skills. Children from the Premature Group appear to reflect many of these deficits and therefore PIQ is likely a good indicator of neuropsychological integrity for these children.

This is not surprising as both groups of children were also significantly different with respect to their performance on global neuropsychological measures with the Prematures clearly illustrating more impaired performance. The relationship of poor performance on neuropsychological measures and Performance IQ can be demonstrated by a recent study evaluating the VIQ/PIQ performance of a large sample of LD children in relation to global neuropsychological measures. A subsequent regression analysis indicated that Performance IQ was the best predictor of neuropsychological impairment in the sample while traditional Verbal - Performance discrepancies were not (Shine & Dean, 1992).

Prior studies have not directly evaluated the dimensions of PIQ / VIQ for Prematures, as most studies included only FSIQ data. Yet several hypothesis have been formulated to account for greater variation and/or deficit noted for PIQ compared to VIQ for high-risk children. Among these is the notion that VIQ scores often tap more "crystalized" or acquired learning and/or knowledge concepts while PIQ scores often relate to more "fluid" or abstract, non-verbal and perceptual-motor learning concepts including mental efficiency, leading to relative "stability" of the VIQ in relation to PIQ where new or novel information is introduced under time constraints. The neuropsychological significance of patterns of performance on global IQ measures is particularly important with respect to subtypes of dysfunction especially for those functions that appear to be more dependent on right hemispheric skills as discussed above.

Some recent theorists including Rourke, have concluded that VIQ scores represent "overlearned" skills and are therefore less sensitive to more subtle brain dysfunction when compared to PIQ scores which appear to be more sensitive to a variety of neurodevelopmental deficits leading to "nonverbal" deficits (Rourke, 1982; 1987; 1989; Rutter, 1982). This finding has been consistently demonstrated by a number of studies conducted on children with known or acquired early trauma to the central nervous system including early cranio-cerebral trauma and head injuries (Ewing-Cobbs, Fletcher, & Levin, 1985; Fletcher & Levin, 1988; Taylor, 1984), acute lymphocytic lukemia (Copeland, Fletcher, Pfefferbaum-Levine, Jaffe, Reid, & Maor, 1985; Fletcher & Copeland, 1988; Taylor, 1987), untreated hydrocephalus (McNitzky & Bigler, 1990; Rourke, Bakker, Fisk & Strang, 1983; Rourke, Fisk, & Strang, 1986), and cerebral palsy of perinatal as opposed to postnatal etiology (Rourke, 1988b). In many of these cases, deficits in nonverbal intellectual performance (relative to verbal intellectual skills) was noted in addition to poor visual-motor and psychomotor skills, poor problem solving, memory and learning deficits, and reduced mental efficiency; all of which are tapped by PIQ subtests. Rourke contends that these deficits are largely due to destruction and/or dysfunction of white matter particularly within the right hemisphere as noted by the above studies.

Recent investigations provide convincing support for the white matter destruction hypothesis of the NLD model advocated by Rourke. In a recent study examining the relationship of cognitive skills and quantitative imaging (MRI) measures of cerebral white matter in hydrocephalic children, a strong correlation was noted between nonverbal cognitive skills and size of the corpus callosum, compared to normal children with no history of CNS dysfunction. The researchers concluded that there appears to be a relationship between early malformations of the corpus callosum, other changes in white matter, and subsequent reduction in nonverbal cognitive skills (Fletcher, Bohan, Brandt, Beaver, Throstad, Brookshire, Francis, Davidson, & Thompson, 1993). The effect of early damage or dysfunction in specific neurochemical mechanisms of the developing brain , particularly with respect to cerebral white matter is also noted in another recent study evaluating developmental outcome for children with congenital hypothyroidism compared to a group of normal controls (Rovet, 1993). This study noted that hormones excreted by the Thyroid gland have been known to effect a variety of neurodevelopmental processes including myelin formation. The results of the long-term prospective study noted delays in early language development, gross motor problems, deficits in visuo-spatial, psychomotor, and auditory processing skills, arithmetic and reading comprehension, attention and social competence, consistent with the NLD model. This research identifies the important role that thyroid hormones play in encoding the genes for myelin-associated-glycoprotiens which form a large proportion of white matter and that dysfunction of these vital hormones at the molecular level provides convincing evidence for the white matter destruction or malformation hypothesis outlined by Rourke.

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comprehension, attention and social competence, consistent with the NLD model. This research identifies the important role that thyroid hormones play in encoding the genes for myelin-associated-glycoprotiens which form a large proportion of white matter and that dysfunction of these vital hormones at the molecular level provides convincing evidence for the white matter destruction or malformation hypothesis outlined by Rourke. The connection between early destruction of white matter and subsequent neuro-developmental deficits similar to NLD is also seen among children with Asperger's syndrome (Sparrow, 1993).

The findings of the current study appear to support the hypothesis that lower Performance IQ scores indicative of possible deficits in nonverbal problem solving particularly in novel situations, are more likely to exist among Prematures compared to normal birthweight children since Prematures are more likely to sustain early trauma to the developing central nervous system. The cognitive, neuropsychological and academic performance of children from the Premature Group appears to bear close resemblance to the neuro-cognitive characteristics of Rourke's Nonverbal Learning Disability paradigm.

Premature Birthweight and Academic Function

With respect to the results of the current study, children from the Premature Group and the Sibling Group were initially compared on their performance on the WRAT-R subtests alone. Significant differences between the groups were noted for the Reading and Arithmetic subtests but not for the Spelling subtest, even though children from the Premature Group scored approximately one standard deviation lower than the mean for normal Siblings. When examining the results further, it was also noted that a significant relationship existed between birthweight of children form the Premature Group and Reading as well as Arithmetic subtest scores on the WRAT-R. In other words, the Premature birthweight group in general showed lower Reading and Arithmetic performance on the WRAT-R even though mean deferences in group performance failed to reach statistical significance when compared to Siblings, at least for the Arithmetic subtest. It may have been that both groups found the Arithmetic subtest to be difficult due to its inclusion of imperial measurement (as opposed to metric) items used in the United States. This is entirely possible judging from the mean performance of both groups which was slightly below the normative mean. Spelling performance was, however, consistently non-significant for both groups, again likely due to level of difficulty and the inclusion of words that may not be directly reflective of Canadian educational curriculum, since both groups performed below normative standards in general.

Analysis of the WRAT-R Reading subtest for LBW versus VLBW Prematures was also conducted in order to investigate potential differences in test performance as prior studies have demonstrated a higher incidence of learning disorders among children with Very Low Birthweight (VLBW), compared to LBW and normative samples. Current results suggest that the LBW Prematures differed significantly from the Sibling Group on the Reading subtest of the WRAT-R while the VLBW Prematures did not. In fact, the mean Reading scores for the VLBW subgroup was slightly higher than the LBW group (statistically significant) and closer to the performance of sibling controls, which was an unexpected finding since VLBW Prematures should have scored lower than controls or the LBW subgroup in most cases. It is possible that reduced sample size may have effected these results or that the VLBW subgroup sampled here may not be entirely representative of the larger population of VLBW Prematures. In can be concluded therefore, that the children from the Premature Group tend to score significantly lower than a group of normal Siblings on tests of reading recognition and that children from the LBW subgroup (heavier Prematures) are likely to display this pattern compared to VLBW (smaller) Prematures.

Analysis of the Spelling subtest performance of the WRAT-R for LBW versus VLBW Prematures resulted in significant differences between the VLBW and LBW subgroups but not when compared to Sibling Controls for each subgroup. In other words, the mean spelling performance on the VLBW Prematures was higher and more like the performance of sibling controls when compared to LBW Prematures who scored more than one standard deviation below test norms. It is possible that reduced sample size may have effected these results or that the VLBW subgroup sampled here may not be entirely representative of the larger population of VLBW Prematures. In can be concluded therefore, that children from the Premature Group did not differ in their Spelling performance when compared to Siblings likely due to differences within the Premature Group as the VLBW subgroup scored higher (statistically significant and similar to Siblings) than LBW children and therefore affected the overall mean performance on the WRAT-R Spelling subtest when compared to Siblings. Subgroup differences may therefore exist in larger samples of LBW and VLBW Prematures with respect to WRAT-R Spelling performance, however, the results of the current study suggest that children from the LBW subgroup (heavier Prematures) illustrated poorer performance when compared to VLBW (smaller) Prematures.

Analysis of the Arithmetic subtest performance of the WRAT-R for LBW versus VLBW Prematures did not result in significant differences when compared to sibling controls for each subgroup even though their mean performance was clinically lower than their Siblings. This is an unexpected finding as it was felt that the VLBW subgroup would likely score lower on this subtest. In fact, a significant relationship was noted between birthweight of children from the Premature Group and Arithmetic subtest performance. Again the unexpected results are likely due to small sample size for both groups and the fact that both the Premature and Sibling Groups may have found the test items to be too difficult or not consistent with the Canadian educational curriculum (non-metric items).

Significant differences between the Prematures and Siblings groups of children were not generally noted across all WRAT-R subtests (aside from the Reading subtest), since these results represent a direct or observable performance of both groups of children without the inclusion of specific criteria such as clinical cut off scores required for Learning Disability diagnosis. Current definitions of LD include specific criteria stating that intellectual scores must reside within the "average range" while academic achievement scores must be significantly below the average range for age or grade expectation. Depending on the setting, researchers and clinicians have frequently used a one standard deviation below the mean cut off (15 standard score points) as inclusion criteria for academic underachievement on WRAT-R. The current study used more conservative criteria and chose to exclude children with substantially low IQ (FSIQ < 80), as one of the criteria for Learning Disability diagnosis while including children with below average standard scores on any given achievement tests (WRAT-R subtests < 80). Although low achievement scores are also noted for children with low IQ, as more general cognitive factors appear to be lowering academic achievement and by clinical definition, these children were not be considered as LD.

Based on this very basic criteria for LD diagnosis, the current research sought to investigate the relationship between LD and low birthweight by comparing the performance of the Premature Group with the performance of normal birthweight Siblings as well as the performance of lower (VLBW) versus higher (LBW) subjects within the Premature sample. This analysis was conducted with three specific subgroups in mind based on Rourke's (1985) general criteria for LD subgrouping (modified). A Global LD group was identified based on underachievement on all three WRAT-R subtests and average FSIQ. A Language LD group was identified based on poor performance on the WRAT-R Reading and Spelling Subtests and average FSIQ. An Arithmetic LD group was also identified based on poor performance on the WRAT-R Arithmetic subtest and average FSIQ. In fact, the current subgroups were based on more strict criteria (deficits greater than one standard deviation) than described by Rourke (1985), in an attempt to incorporate more conservative estimates of LD subgroups within the population of Prematures.

Current results indicate that none of the children in the Sibling Group could be classified as LD for any of the subgroups described above. Therefore LD subgroups were only identifiable among children from the Premature Group which is a highly significant finding, indicating the strong association between LD and premature birthweight with this particular sample of non-referred Prematures in comparison to Siblings. The results also suggest that children from the Sibling Group are likely representative of the normal population since none of their test scores were outside normal limits when compared to published norms. It is interesting to note that despite the relatively "normal" presentation of children from the Sibling Group, some of them had brothers or sisters with premature birthweight that were classified as LD. Since some of these children came from the same family of origin, socio-economic status (SES) may have played a smaller part in the outcome or subsequent development of Learning Disability. However, the powerful influence of SES was simply not negated by including Sibling Controls in the current study as many Prematures did not have Siblings to act as comparative normals (within the family). In fact, supplemental analysis conducted on parental history indicated that the education levels of mothers in the Sibling Group was significantly different (higher) than mothers of the Premature Group. This was also true for fathers however, their mean educational rating was not found to be statistically different for the two groups. Occupational level also differed significantly between parents of the Premature Group and the Sibling Group with both parents of children from the Sibling group indicating that they were employed in jobs that had slightly higher SES. In addition, it was noted that mothers of children from the Premature Group reported that they also experienced some learning problems in their own school history while mothers of children in the Sibling Group did not report this, indicating that both groups may have been quite different from each other. Interestingly, the fathers of both groups of children reported experiencing some difficulties in school learning in their own history and therefore these groups may have been quite similar in that both admitted to having had some degree of learning difficulty. These results suggest that SES variables may still have exerted a strong influence in the development or expression of LD among children in the Premature Group.

Since LD was identified only in children from the Premature Group, an analysis of subtypes in relation to lower (VLBW) versus higher (LBW) Prematures, was conducted. The proportion of children with Global LD (impairment on word recognition, spelling and arithmetic,with average FSIQ criteria) was not found to be significantly different among children with LBW versus VLBW as both subgroups of Prematures contained children classified as Global LD. Clinically, however, a difference was noted as approximately 17% of the VLBW children were identified as Global LD compared to approximately 25% of LBW children. This represents an interesting and perhaps unexpected finding as one would have expected perhaps a higher rate of classification among VLBW Prematures as these children appear to be traditionally at risk for a host of developmental disorders. On the other hand, these results may also suggest that the subsequent development of Global LD may have more to do with destruction and / or dysfunction of the brain at perhaps a later or more crucial developmental stage of white matter development as suggested by Rourke's model. The general results, however, appear to confirm earlier findings that suggest the strong association between low birthweight and the subsequent development of Learning Disability.

Other subtypes of LD were also investigated by the current study. Among these included Language LD classified by poor performance on WRAT-R Reading and Spelling subtests with average FSIQ on the WISC-R. Again, none of the children in the Sibling Group were identified as Language LD when compared to the Premature Group where several children met the criteria. No significant differences were noted with respect to subgroups of LBW and VLBW Prematures and Language LD. However, approximately 30% of the LBW Prematures compared to approximately 17% of the VLBW Prematures were classified as Language LD. Clinically, this finding again may support the above theoretical model as LBW Prematures appear to be more at risk for the development of Language LD compared to VLBW Prematures sampled in the current study. It may also be, however, that the negative effect of small sample size and/or sampling error may have contributed to these unusual findings as larger samples of both subgroups may have identified significant differences in the proportions noted above. The findings would therefore have limited generalizability to the larger population of Prematures particularly since other studies have identified language-based disabilities in VLBW Prematures (Boswel, 1987).

The most interesting results of the current study can be found when evaluating the performance of Prematures for the Arithmetic LD subtype; identified by low scores on the WRAT-R Arithmetic subtest and average FSIQ on the WISC-R. Once again, none of the children in the Sibling Group could be identified as Arithmetic LD, indicating that only the Premature Group contained Arithmetic LD children. However, statistically significant differences were noted in comparing the performance of LBW versus VLBW Prematures for Arithmetic LD. The results further indicated that none (0%) of the LBW Prematures could be classified as Arithmetic LD while approximately 25% of the VLBW Prematures could be classified in this manner. The results suggest that Learning Disabilities in arithmetic function were evidenced in only children with Premature birthweight histories and specifically only within the VLBW subgroup. This was anticipated in the research hypothesis due to the interplay of visual-spatial components and the development of mathematical skills. This finding has been recently demonstrated by Griffith, Rattan and Sujansky (1991) who investigated visual-spatial, auditory-temporal, and visual-temporal patterns in relation to reading and mathematical performance among LD children. Their results using computerized instruments, suggested a significant relationship between auditory and temporal skills essential to the reading process as opposed to visual and spatial processing skills which seemed essential for mathematical performance. The results of the current study are therefore very compelling with respect to the application of Rourke's NLD model since children at highest risk (VLBW) displayed arithmetic deficits, implying that these children may have suffered relatively more destruction of white matter within the right cerebral hemisphere since their deficits were likely due to earlier developmental insult when compared to LBW Prematures. In fact this subgroup of children did show a greater degree of impairment on the HRNB compared to the LBW subgroup, suggesting further support for this hypothesis. Some caution should be exercised in these neuropsychological interpretations in the absence of direct physical evidence such as MRI.

The current results suggest a much stronger association between disabilities in arithmetic for children with VLBW in the current sample. Children with LBW appeared to have more indicators of Language and/or Global LD compared to VLBW children at least from a clinical perspective. Generally speaking however, only children from the Premature Group were identified as Learning Disabled for either the Global, Language or Arithmetic subtypes. Children in the Sibling Group were not identified as having any Learning Disability and therefore performed more like the normal population.

It would appear therefore, that the current results tend to support earlier conclusions that children with premature birthweight history tend to have a higher degree of association with Learning Disabilities in general, compared to their counterparts (in this case Siblings) with normal birthweight. This may explain yet another finding from the study that clearly highlights the continued high-risk nature of presentation for children with premature birthweight histories. As noted earlier in the literature review, Prematures tend to be over-represented in special education classrooms. This is clearly supported by the current study in a sample of non-referred Prematures as significant differences between Prematures and Siblings were noted with respect to enrollment in or need for special education intervention. None (0%) of the children in the Sibling Group required any form of special education assistance as opposed to approximately 56% of children in the Premature Group who required such assistance. These findings provide convincing evidence that children with premature birthweigth histories often require some type of additional assistance or special education support likely due to a variety of learning deficits and/or deficiencies that may not be severe enough to be classified as Learning Disabilities, but which clearly require attention and subsequent intervention.

Premature Birthweight and Neuropsychological Function

As noted earlier, the general results of the current study appear to support Rourke's NLD model particularly with respect to neuro-cognitive dysfunction. This can be demonstrated by an analysis of the neuropsychological performance of Prematures compared to normal birthweight Siblings. In accordance with this model, children with NLD are noted to have significant neuropsychological deficits in bilateral tactile-perceptual skills, usually more marked on the left side of the body, impaired visual discrimination, recognition of detail and visual relationships, deficits in visual-spatial organizational abilities and bilateral psychomotor coordination problems, again, more marked on the left side of the body. Their attention to tactile and visual input is often poor. However, their attentional skills for complex, novel nonverbal material is often also poor. These children also display significant deficits in concept formation, problem solving and mental flexibility particularly for novel information. Rourke adds that children with NLD also tend to display strengths in simple repetitive motoric tasks, auditory-perceptual skills, repetition of rote material, and basically most aspects of auditory function, including excellent phonemic hearing, segmentation, blending, repetition and receptive language skills.

With respect to higher cortical functions and global measures of neuropsychological integrity for all Premature subjects in the current study, a significant correlation between birthweight and composite scores on the HRNB was noted. This was an expected finding as it was hypothesized that lower birthweight would be associated with more impaired neuropsychological performance on the HRNB-C. Further support for this finding can be gleaned from examining the performance of a single (global) measure of neuropsychological function such as the Category Test. The correlation between birthweight of the Prematures and Category Test performance was very significant ($p = .009$), indicating that more impaired scores were associated with Premature birthweight.

With respect to global neuropsychological performance, it was noted that children from the Premature Group differed significantly from children in the

Sibling Group for composite performance on the HRNP In fact, the mean scores for children in the Premature Group were well into the mild to moderate range of brain dysfunction when compared to the mean scores for children in the Sibling Group which were notably in the normal range. In comparing the performance of LBW and VLBW Prematures to normal Siblings, on global HRNB scores, significant differences were again observed. However, it was noted that the mean for LBW Prematures was well into the moderately impaired range compared to the mean scores for VLBW Prematures which was slightly but not significantly lower (less impaired performance). Both groups of Prematures, however, did perform significantly below the "normal" mean for normal Siblings as noted above, which suggests that these children appear to have more indicators of brain dysfunction, consistent with Rourke's model.

Rourke's suggestion that children with NLD tend to display deficits in complex nonverbal problem solving and conceptual reasoning particularly in novel situations, is also supported by the current research. It was noted that Prematures as a group performed significantly below the normative mean on the HRNB Category Test , compared to normal Siblings who performed well within normal limits. Significant correlations were also observed between birthweight and Category Test error scores, indicating that lower birthweight was strongly associated with more impairment on this test. In a recent study (Griffith, Rattan, Sujansky, & Lefevre, 1992), evaluating the performance of disabled and normal older children (ages 9-14), Category Test errors were found to be highly correlated with perceptual organization measures including PIQ and moderately correlated with global IQ, suggesting to the researchers that this test is a good measure of right hemispheric functioning, followed by global intelligence. These results suggest that the performance of Prematures as a whole was more impaired with respect to this highly complex measure of global neuropsychological integrity. Since many of the items involve novel or complex nonverbal problem solving skills, poor performance among children with NLD would be expected and appears to have been confirmed by more impaired mean score performance for Prematures.

On other subtests of the HRNB measuring visual attention and sequencing such as the Trail Making Test, the performance of Prematures compared to Siblings was not statistically different even though it was observed that the premature mean was below the sibling mean. This nonsignificant finding appears not to fit the NLD model as the highly visual nature of the subtests should have resulted in more impaired performance for Prematures. However, it is likely that these subtests were not challenging enough or did not present enough novel stimuli to elicit the NLD response deficits in visual processing. In addition, the stimuli, consisting of numbers and letters, may be encoded and processed verbally or are "overlearned" stimuli and therefore did not pose significant difficulties for these children. It was observed however, that scores on the Trail Making Test Part A, were highly correlated with birthweight (unlike Part B), which suggests that lower birthweight was associated with poorer performance on Part A of the TMT, traditionally interpreted as a test of right-hemispheric visual processing speed. This may explain the observed clinical differences between the two groups and add some support to the NLD hypothesis.

Attentional skills measured by the HRNB SSPT and SRT subtests did however, provide some support for the NLD hypothesis when compared to Prematures. On tests of phonemic discrimination, and auditory-perceptual skills, the performance of Prematures differed significantly from sibling controls. However, this was likely due to the fact that normal Siblings performed slightly above the normative mean on these subtests. In other words, the performance of Prematures as a group was not significantly below the normative mean, suggesting that they did not have significant difficulties on these complex auditory tests of discrimination, perception and attention, even though statistically significant differences were noted between the groups. This would be generally consistent with the NLD paradigm as these children are thought to have well developed auditory skills in general.

The NLD model discussed above noted bilateral deficits in complex psychomotor and tactual-perceptual tasks among children with NLD. The mean performance of the Premature Group, compared to the Sibling Group on the HRNB Tactual Performance Test, tended to support this paradigm as significant differences were noted on all three trials of the TPT involving the performance of the dominant, nondominant and both hands on a highly complex test of tactual-motor-kinesthetic learning. Although the Prematures in general managed to learn this task, judging from their mean scores which were within the broad average range compared to the normative mean, they performed below the level of normal Siblings and did not display the normal pattern of at least a 30% reduction in speed of learning, compared to Siblings. A more striking difference in performance between the two groups of children is noted however, on the remaining measures of the TPT. On the one hand, no significant differences were noted on the Memory subtest in which the children had to recall the number and shape of the blocks used. While this subtest clearly has some tactual memory component, there also appears to be a strong verbal memory component and therefore it is possible for subjects to use verbal encoding strategies to perform well on this task. This may account for the relatively normal mean performance on the Premature Group and lend further support to the NLD hypothesis. However, significant differences were noted on the Localization subtest of the TPT in which the subject has to correctly locate the blocks on a two dimensional surface (drawing). The Prematures as a group tended to underperform on this subtest when compared to normal Siblings likely due to the spatial memory component of the test and in doing so tended to support the NLD hypothesis.

Children from the Premature Group differed significantly from normal Siblings with respect to their mean neuropsychological performance on tests of complex sensory-perceptual function (SPE) on the HRNB. These subtests consist of simple tactile, auditory and visual input measures in addition to more complex tests of tactile-kinesthetic skills including finger agnosia, graphesthesia, sterognosis, and tactile-perceptual discrimination. These skills are frequently deficient among children with Learning Disabilities and are suggestive of neuropsychological brain dysfunction of the sensory cortex of the parietal lobe region. Support for this reported finding can be noted in the current results to some degree particularly when viewing the supplemental correlation coefficients between academic achievement scores and performance on more complex sensory-perceptual subtests of the SPE. Significant correlations were noted between Arithmetic scores and the Finger Agnosia Test as well as the Fingertip Number Writing Test, both measuring higher sensory-perceptual functioning particularly within the parietal lobe region. Significant correlations were also observed for Reading scores and Fingertip Number Writing and Tactile Form Recognition, again in support of earlier conclusions of a connection between complex sensory functions and the substrate required for later development of some academic skills. Complex sensory deficits are frequently also observed among Prematures as noted in the literature review, and results of the current study tend to support this. In fact, significant differences between the Premature Group and the Sibling Group were noted for specific subtests of the SPE, including the presence of Imperception errors, Finger Agnosia and Fingertip Number Writing, for the Premature Group to a much higher degree than noted for the Sibling Group. These results provide some support for the NLD hypothesis although specific deficits such as more impaired performance for the left side of the body were clinically observed for Prematures but were not noted to be statistically significant when compared to Siblings, likely due to small sample size.

The motoric performance of Prematures compared to Siblings was generally not found to be statistically significant, indicating that both groups of children performed adequately on tests of motor strength, simple motor speed and fine motor dexterity, even though the Premature Group mean was clinically lower than the Sibling Group mean in every case. However, some differences were observed in comparing the performance of the dominant versus nondominant hands for both groups of children. Specifically, it was noted that dominant hand function for Prematures was significantly different than Siblings on simple repetitive motor speed tasks (FTT), and fine motor dexterity tasks (GPT). These results are not consistent with the NLD hypothesis and generally support earlier conclusions suggesting no broad differences in basic motoric skills among Prematures on these variables, perhaps due to their non-complex and highly repetitive nature. In other words, these skills tend to be over-learned and therefore may not be the best indicators of more subtle dysfunction since they involve relatively localized regions of the anterior cerebral hemispheres.

The neuropsychological performance of Prematures compared to Siblings was also evaluated on tests sensitive to aphasic symptoms (Aphasia Screening Test). The results suggest that as a group, the Prematures performed well below the average range and significantly different when compared to Siblings. This is not a surprising finding as children with a diagnosis of Learning Disability tend to display a variety of aphasic symptoms, indicative of more subtle brain dysfunction particularly with respect to language systems. Supplemental analysis on selected subtests of the AST indicated a significant correlation between birthweight and Spelling Dyspraxia, Dysnomia, and Central Dysarthria, aphasic symptoms more likely indicative of left-hemispheric disorders, and Constructional Dyspraxia, often implicated in right-hemispheric disorders. Significant correlations were also observed between these indicators of aphasia and performance on the Reading, Spelling and Arithmetic subtests of the WRAT-R. That is to say, lower birthweight was associated with these specific pathognomonic indicators of aphasia and with performance on achievement test. It was further observed that Prematures differed significantly from Siblings with respect to the presence or absence of these symptoms associated with aphasia including Constructional Dyspraxia, Spelling Dyspraxia, Dysgraphia, Right-Left Confusion and Dyslexia. Since none of children from the normal Sibling Group displayed these symptoms, it can be concluded that Prematures in this sample evidenced a significant number of aphasic symptoms, consistent with neuropsychological brain dysfunction. In addition, there appeared to be a significant pattern to the number and magnitude of differences observed among Prematures compared to Siblings. Virtually all of the highly significant differences noted between the groups were observed on aphasic symptoms frequently connected with right-hemisphere disorders including Constructional Dyspraxia, Dysgraphia, R-L Confusion and to some extent, Spelling Dyspraxia, while only one symptom (Dyslexia) connected with left-hemisphere disorder, was noted. This provides some possible evidence for the NLD hypothesis with respect to greater involvement of right hemispheric systems among children with premature birthweight as these systems are noted to precede later developing left hemisphere systems from an ontological point of view.

The literature review indicated that a host of neurodevelopmental deficits are noted among children with premature birth histories. It was also hypothesized that significant differences in neuropsychological performance would likely exist within this population and that these deficits would likely involve global brain dysfunction resulting in deficits of "fluid" abilities or those involving higher conceptual reasoning particularly when novel problem solving stimuli are encountered. The results of the current study suggest that this sample of non-referred children with premature birth history appeared to illustrate more impaired performance on global neuropsychological measures compared to Siblings with normal birthweight history. It was also noted that significant differences existed between the two groups on selected measures of complex nonverbal and abstract reasoning, nonverbal or spatial memory skills, nonverbal attentional skills, complex sensory-perceptual processes and aphasic symptomatology, as the performance of Prematures was clearly impaired compared to Siblings. In many cases, the pattern for dysfunction among Prematures suggested greater involvement of right hemispheric systems, consistent with the Nonverbal Learning Disability paradigm outlined by Rourke (1982; 1987).

While these global differences provided evidence for many of the central hypothesis of the current research, some aspects of the results with respect to subgroups of Prematures were not consistent with prior research. This research frequently noted greater dysfunction among children with VLBW as these children appear to have more adverse medical complications and therefore a greater degree of morbidity and mortality. This has clearly been demonstrated by early medical research on developmental outcome including "hard" neurological deficits such as Cerebral Palsy, Hydrocephalus, and other more chronic or observable Developmental Disabilities. However, relatively little research has been conducted on more subtle disorders such as Learning Disabilities. The results of the current study suggest that the degree of impairment associated with premature birthweight history appears to be more pronounced for children with LBW when compared to VLBW, possibly due to more developmental vulnerability of LBW Prematures for more subtle dysfunction as opposed to "hard" or more observable deficits often associated with VLBW Prematures.

The results also provided support for more detailed neuropsychological assessment procedures compared to more traditional psycho-educational assessment particularly for this subgroup of children. If clinicians were to rely on the results of brief psycho-educational procedures to evaluate this group of children, they would likely note no significant differences in some global IQ scores such as Verbal IQ, and therefore erroneously conclude that these children may not evidence significant brain dysfunction or significant deficits in language-based learning such as word recognition skills or spelling ability. To support their conclusions, they may point to the relatively high rate of speech production often noted among Prematures or the fact that they tend to perform well on auditory-linguistic measures. In fact, underlying "nonverbal" deficits may not be directly evident in traditional psycho-educational procedures or be only manifest in global scores such as low Performance IQ in relation to Verbal IQ, low scores on arithmetic achievement tests, or perhaps other measures of visual processing. In addition, these low scores could also be explained by other means such as speed factors or perhaps emotional difficulties including low motivation, depression, or attentional problems, instead of essential features of NLD. The findings of the current study strongly support the utility of neuropsychological procedures particularly for the assessment of more subtle dysfunction even among older children with premature birth history. In a recent study evaluating the utility of neuropsychological procedures on a very large sample of LD children with low, average or high IQ, it was noted that a modest overlap exists between IQ measures and neuropsychological indicators of brain dysfunction, indicating that these measures assess different sets of abilities (Kundert, McIntosh, & Dean, 1992). Neuropsychological procedures therefore likely tap more subtle functions which in some cases appear to be less related to IQ, or provided more detailed brain-behavior observations that could lead to more accurate diagnosis and therefore more appropriate recommendations and intervention

Premature Birthweight and Visual-Motor Integration

Perceptual-motor deficits in younger children with premature birth histories have been well documented by prior studies noted in the literature review. However, this analysis has not occurred among the older Prematures who are often observed clinically to display complex visual-motor integration deficits in addition to Learning Disabilities. In other words, these children often fail to display the normal developmental progression of visual-motor integration observed in their normal birthweight counterparts. The results of the current study noted significant differences between Prematures and normal birthweight Siblings on a measure of complex visual-motor integration (Bender Test). Deficits in this area are often noted among children with Learning Disabilities primarily due to the high degree of correlation often observed between low achievement, IQ and neuropsychological performance, and poor visual-motor integration (VMI). This was also demonstrated by current results where significant correlations were noted for Bender test performance and Full Scale IQ, Verbal IQ, Performance IQ, Reading and Arithmetic scores, Trail Making Test B, and composite HRNB performance. In addition, lower scores for visual-motor integration were also correlated with indicators of delayed language and motor skills, lower birthweight and psychopathology. This is not an unusual finding as poor visual-motor integration is often indicative of brain dysfunction particularly among older children who should have improved in these skills based on developmental maturity alone. The relationship between poor visual-motor integration and brain dysfunction is also evident as the neural circuitry required for adequate performance on these tests tends to follow well established association, commissural, and projection fiber pathways often implicated in a variety of learning disorders particularly for the left cerebral hemisphere. The impaired performance of children from the Premature Group is demonstrated by their mean score which was notably in the impaired range and approximately two standard deviations below the normative mean, while the mean performance of the Sibling Group was exactly at the normative mean for other children of the same age. Impaired performance of the Premature Group can also be illustrated by noting that approximately 78% were classified as having abnormal Bender performance based on the number and magnitude of errors, while only 22% had normal Bender performance. None of the children in the

Sibling Group evidenced any abnormal Bender performance. These results tend to support the NLD hypothesis which indicates that complex visual-perceptual deficits are more likely to exist in among children with NLD. In the case of older Prematures, this finding may suggest a greater degree of dysfunction and/or destruction of white matter fiber tracts for both cerebral hemispheres with notable deficits for right hemispheric disorders, as hypothesized by the NLD model.

Premature Birthweight and Psychopathology

A number of prior investigations have frequently implicated the presence of a variety of psychopathological disorders among children with developmental disability, high-risk birth and head trauma including brain dysfunction (Rutter, 1982; Tramontana & Hooper, 1992). In some cases these children run a five times greater risk for developing psychopathology compared to children who have not suffered brain insult. These studies have also noted that children with specific brain injury run a two times higher risk of developing psychopathology when compared to a matched sample of disabled children with physical handicaps not involving the brain. Furthermore, it was noted by Rutter (1982) that children with severe head injuries (post-traumatic amnesia greater than 7 days) also had a two times higher risk for developing psychopathology compared to children with mild head injuries (post-traumatic amnesia less than 7 days), and to a matched sample of children with orthopedic injuries. While it was known in early research that brain damage often lead to a host of social-emotional and behavioral difficulties, this population was viewed as a homogeneous group of children. It was also assumed that brain injury was randomly distributed in the population. Current studies have clearly noted the heterogeneous nature of brain injured subjects and noted that brain injuries are not evenly distributed in the population. The mere fact that children with Attention Deficit Disorder (ADD) are more likely to get into accidents and therefore subject to their fair share of head injuries attests to this. Researchers have also noted that the risk factors for the development of psychopathology are greater for children with known brain damage as well as in children with epilepsy, low IQ and other neuropsychological disorders, including previous history of behavior disorder.

In a search for possible etiology, researchers have noted the presence of structural deficits among children with psychopathology including reduced right hemisphere densities on MRI scans as well as abnormal EEG, and the presence of more indicators of disordered or dysfunctional right hemispheric processes (Kerstesz & Dobrowolski, 1981; Rourke, 1988; Rutter, 1982; Voeller, 1986). In addition to advocating the relative superiority of neuropsychological procedures over traditional techniques, these researchers have noted a number of neuropsychologically-based psychopathological disorders which they feel are more attributable to right hemispheric deficits (Baron, 1987; Fletcher & Levin, 1988; Manoach, Sandson, Mesulam, Price, & Weintraub, 1993; Silver, Elder, & DeBolt, 1993; Stefantos, Reid, Seals, & Ontiveros, 1990; Strang & Rourke, 1985; Tramontana & Hooper, 1992; Tranel, Hall, & Tranel, 1987; Weintraub & Mesulam, 1983). These studies have noted the relative superiority of the right hemisphere in the recognition and processing of emotional responses in relation to left hemispheric self-inhibitory processes. They note that displays of emotion are frequently noted on the right side of the face or that various conversion reactions are manifested on the left side of the body. Some neurochemical processes related to mood also appear to be lateralized to the right hemisphere, particularly with respect to increased receptor sights for serotonin and norepinepherine both cortically and subcortically at the level of the right thalamus (Corballis & Morgan, 1978; Kertesz 7 Dobrowolski, 1981;Tranel, Hall, & Tranel, 1987).

These findings are entirely consistent with Rourke's NLD model (1982; 1987; 1988) in which he describes a unique set of socio-emotional and/or adaptive deficits in children with NLD. He contends that children with NLD tend to have significant difficulty adapting to novel situations and display an over-reliance on prosaic or rote behaviors that are frequently judged by others as inappropriate. They also display significant deficits in social perception, social judgement and social interactions skills with a marked tendency toward social withdrawal including social isolation with increased age. He further states that there appears to be a developmental progression in psychopathology from early indicators of acting-out or disorders of conduct to later stages where these children often "internalized" forms of psychopathology including excessive anxiety, depression, and other forms of socio-emotional disturbance. In addition, early manifestations of hyperactive behavior may become transformed into hypoactive behavior with advancing years. These children often try to compensate for social judgement deficits by an over-reliance on verbal skills but miss the subtle nuances of language. As a result they are often deficient in social skills. In addition, since they often do not evidence learning problems in reading or spelling and appear to have no significant deficits with respect to language production (rate), they may never be referred for an evaluation. Their apparent deficits in mathematics may not even be considered as significant since these deficits are frequently disregarded by classroom teachers as manifestations of "instructional weakness". Furthermore, their apparent manifestations of internalizing disorders particularly in older children, may also go unnoticed compared to the more flamboyant or disruptive behavior disorders that get instant recognition and referral for evaluation by teachers. or parents. In short, these children appear to be at greatest risk since their problems may be more subtle yet quite incapacitating.

The results of the current study provide some evidence for NLD among Prematures compared to normal birthweight Siblings. Generally speaking, Prematures differed significantly from Siblings for specific indicators of psychopathology on clinical rating. In other words, approximately 88% of children from the Premature Group were rated as having some type of psychopathology compared to only 16% of children from the Sibling Group.. Significant correlations were also noted between birthweight of the Prematures and psychopathology, suggesting that lower birthweight values were associated with more indicators of social-emotional and behavioral deficits. This significant finding has not directly been noted among previous studies and suggests that Prematures may have significant psychopathology that appears to exceed their Learning Disability deficits and therefore may present more of a problem with respect to remediation.

With respect to the pattern of psychopathology noted among Prematures it was hypothesized that attentional deficits are likely to exist since these deficits are often observed among children with brain dysfunction and/or impairment. In evaluating children for the clinical presence of Attention Deficit Disorder with Hyperactivity (ADD-H), no significant differences were noted between the Premature Group and the Sibling Group despite the fact that approximately 47% of the Prematures and only 13% of the Siblings were classified as ADD-H. The lack of significance is likely related to small sample size particularly for the Sibling Group. However, there appears to be a clinical difference between the groups as expected. Furthermore, significant differences for Attention Deficit Disorder without Hyperactivity (ADD) between the groups was not noted despite the fact that approximately 28% of the Prematures were rated in this manner compared to none (0%) of the Siblings. However, significant correlations were noted between birthweight of children from the Premature Group and ADD and

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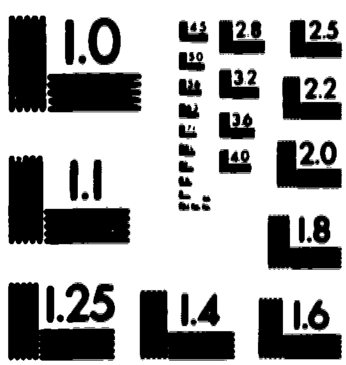
PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT



PRECISION℠ RESOLUTION TARGETS

ADD-H. This is significant in that the relationship between ADD and lower birthweight values likely indicates that Attentional Deficits (with or without hyperactivity) may be associated with prematurity but perhaps may not be of sufficient magnitude to be classified as a disorder. The idea that there may be more indicators of attentional deficit among Prematures was readily observed in the authors own clinical work on a case by case basis, and was hypothesized in the current study. Although statistical differences between the Premature Group and the Sibling Group were not evident, clinical differences between the groups were apparent particularly for ADD as noted also by significant correlations between Premature birthweight and ADD as well as ADHD. A age-related breakdown of the data related to this disorder did not take place which is unfortunate as it may have provided some support for the NLD hypothesis particularly if younger children displayed ADD-H while older children did not. However, these relationships between attentional deficits and prematurity must not be ignored as there may be some important connections between these and the NLD hypothesis noted earlier.

This possibility is further supported by some researchers who have indicated that some children with dyslexia also tend to display abnormal brain symmetry particularly in the region of the planum temporale and parietooccipital cortex that may be associated with language delay and possibly handedness. After examining postmortem and cytoarchitectonic studies, they conclude that there is evidence of thalamic involvement and a distribution of focal dysplasias involving the left frontal, left temporal and right frontal regions (Hynd & Semrud-Clikeman, 1989). More importantly, relationships between dyslexia and ADD-H were further investigated with respect to differences in brain morphology in a group of dyslexic children compared to a group of ADD-H children. This study noted that both the dyslexics and ADD-H children had significantly smaller right anterior width measurements of the planum temporal, compared to normals. The dyslexics also had bilaterally smaller insular region and significantly smaller left planum than normals. In addition, approximately 70% of the normals and ADD-H children had the expected pattern of left plana greater than right (asymmetry) while only 10% of the dyslexics showed this pattern. They concluded that this symmetry or reversed symmetry of the plana among dyslexics may relate to deviations in normal patterns of corticogenesis (Hynd & Willis, 1988). The important finding of normal brain asymmetry among ADD-H children was further evaluated in comparison to a group of ADD children without hyperactivity (Hynd, Lorys-Vernon, Semrud-Clikeman, Nieves, Huettner, & Lahey, 1991). This study noted that children with ADD alone displayed significant deficits in academic achievement particularly in mathematics. These children were also slower in rapid naming tasks and approximately 60% had a co-diagnosis of Developmental Reading and Arithmetic disorder while none of the ADD-H children were classified in this manner. On the other hand, approximately 40% of the ADD-H children were classified as having a Conduct Disorder and were rated by their parents as being significantly more active, impulsive and deviant with respect to age-appropriate skills. It was concluded by the researchers that ADD children without hyperactivity may suffer from a right hemisphere syndrome.

The possibility that children with ADD displaying features of the NLD syndrome is further supported by research indicating that these children frequently display poor social skills including anxiety in addition to underachievement and the presence of Learning Disabilities, while ADD-H children do not (Hynd & Semrud-Clikeman, 1989; Hynd, Lorys-Vernon, Semrud-Clikeman, Huettner, & Lahey, 1991; King & Young, 1982; Lahey, Schaughency, Strauss & Frame, 1984;Saunder, DeMarco, Fruitiger, & Levey, 2988; Voller, 1986; Voller & Heilman, 1988). Some studies have also noted differences in pharmacologic response related to subtypes of ADD children (Ternes, Woody, & Livingstone, 1987; Union, 1988), or the presence or absence of sensorimotor deficits and "soft signs" (Hern & Hynd, 1992). Considering the fact that many children in the Premature group met the characteristics for NLD, it seems conceivable that many may also meet the criteria for ADD if sufficient sample size was used in the current study.

The current study did find evidence for the presence of Conduct and/or Oppositional Defiant Disorder among Prematures. Unfortunately, both disorders were coded on similar axes and therefore a breakdown of subtypes was not possible. Treated as a unitary disorder, significant differences were noted between the Premature Group and the Sibling Group as approximately 38% of the Prematures were classified in this manner while none (0%) were classified as having a Conduct or Oppositional Disorder in the Sibling Group. In addition, significant correlations were also observed between this variable and birthweight indicating that lower birthweight values were associated with clinical ratings for both these disorders. This appears to be a significant finding that was not readily evident in the authors own experience in working with these children since attentional deficits were more apparent. However, it appears that a detailed analysis of background variables in addition to in-depth interviews with parents, yielded data that suggested a connection between low birthweight and conduct / oppositional behavior. If this is indeed the case, these children may likely be more at risk for behavioral problems in addition to learning deficits which is likely why a high proportion of low birthweight children often require special education intervention.

Children from the Premature Group were not noted to differ significantly from Siblings with normal birthweight for Anxiety Disorders or Depression even though approximately 28% of the Prematures were classified as having an Anxiety Disorder and 31% were classified as displaying features of childhood Depression on the SIDAC. In some cases such as depressive symptomatology, mean rating scores for the two groups of children were close to significant values ($p = .06$), however these differences were not large enough to reach significance likely due to small sample size in both groups. A significant correlation was noted however, between birthweight of the Premature children and Depression, indicting a possible underlying relationship. Clinical analysis including overall performance during the interview and with respect to parent ratings, appears to indicate that many children from the Premature Group displayed a host of "internalizing" disorders that may not have been severe enough to rate within the "disordered" category and therefore could not be compared directly to the Sibling Group, except for the fact that none of the normal birthweight children evidenced symptoms of depression. Since there was an inadequate sample size to conduct subgroup analysis at different age levels, the developmental progression of acting-out behavior leading to more internalizing problems, consistent with the NLD hypothesis, could not be observed. This would likely make a good topic for further study as would the whole spectrum of psychopathological disorders among Prematures as this type of detailed analysis has not been conducted, aside from the preliminary findings of this study.

Limitations And Suggestions For Further Study

The results of the study provided support for many of the hypotheses indicating significant differences between the Premature Group and the Sibling Group for cognitive, academic, neuropsychological, visual-motor, and emotional/behavioral functioning. A higher proportion of children from the Premature Group were classified as Learning Disabled and demonstrated lower achievement scores particularly for reading among LBW Prematures and arithmetic for VLBW Prematures. More variations in intellectual skills with lower Performance IQ compared to Verbal IQ were noted in the Premature sample with significant correlations noted between birthweight and lower Full Scale and Performance IQ, compared to Siblings with normal birthweight history. More indicators of neuropsychological brain dysfunction were observed among the Prematures with specific deficits noted in more complex, novel and nonverbal problem solving tasks as well as global measures of neuropsychological integrity, complex sensory-perceptual functions and symptoms of aphasia, compared to the Sibling Group who displayed normal performance. Prematures also demonstrated more impaired visual-motor integration compared to Siblings, and, a higher proportion of psychopathology including problems with conduct or oppositional behavior. The study also demonstrated the clinical utility of neuropsychological procedures for children with premature birth history as this comprehensive format allows for the evaluation of more subtle deficits that are not captured by traditional psycho-educational procedures.

Despite the fact that these results provide compelling evidence for a significant association between prematurity and neuro-developmental, academic, and behavioral deficits in a sample of "non-referred" Prematures, it should also be re-iterated that "correlation is not causation" with respect to low birthweight and subsequent observable deficits as this was not the purpose of the current study. In other words, significant correlations or differences between groups do not necessarily mean that a one-to-one relationship exists between the variables. There are a host of other possibilities and variables that can exert an influence on outcome, not to mention the very powerful effect of SES which was also observable in this study with a matched sample of normal birthweight Siblings. The purpose of the study was to simply survey a sample of "non-referred" older children with premature birth histories as defined by birthweight values as well as by gestational age, and to compare their performance on academic, intellectual, neuropsychological and behavioral measures, with a small sample of age-matched Siblings acting as controls. The results are therefore only directly applicable to the children surveyed as well as their normal birthweight Siblings. However, inferences may be drawn to the larger cohort "population" of Prematures born between 1976 and 1983, based on the medical technology available at that time and the age of viability for survival of those Prematures with very low birthweight.

Results of the study suggest a pattern of deficits for Prematures that appears to be consistent with the Nonverbal Learning Disability Syndrome outlined by Rourke (1982; 1987), resulting in a broad spectrum of neuro-cognitive, academic and behavioral deficits possibly due to the destruction and/or dysfunction of white matter particularly for the right cerebral hemisphere as postulated by Rourke and others. Based on the theoretical assumption of early maturation of the right cerebral hemispheres and specifically with respect to white matter ontogenesis, it seems plausible that preterm birth places children at high risk for central nervous system dysfunction particularly with respect to more subtle deficits such as Learning Disabilities which are presumed to be due to CNS dysfunction (Hynd, Marshall, & Gonzalez, 1991). It is possible that low birthweight may expose the neonate to significant destruction of white matter fiber tracts such as the corpus callosum as well as the destruction and subsequent dysfunction of other association and projection fibers particularly in the right hemisphere as these structures are quite fragile, less dense and more vulnerable to insult leading to shearing, tearing or interconnection problems. The plethora of medical complications associated with premature birth including, hypoxia, intraventricular hemorrhage, anemia, respiratory distress, physiologic jaundice, bacterial, viral and fungal infections as well as iatrogenic factors such as hyperoxemia or infections, clearly place these children at significant risk for developmental disabilities likely due to some type of insult to the developing brain systems (Krishnamoorthy, Shannon, Delong, Todres, & Davis, 1979; Landry, Fletcher, Zarling, Chapieski, Francis & Denson, 1984; Nickel, Bennett, & Lamson, 1982).

The results of this study appear to provide some evidence [illegible] NLD hypothesis to hold for children with premature birth histor[illegible] O[illegible] [illegible]ies conducted on Prematures noted earlier, as well as stud[illegible] or children with other medical complications during or shortly following [illegible] may also provide some additional support for the NLD hypothesis. While support for this hypothesis is growing, it must be pointed out that Rourke's formulations concerning right hemisphere white matter destruction, are based primarily on neuropsychological measures with relatively small, carefully selected groups of children being surveyed, and not on clinical postmortem [illegible] neuroimaging evidence. According to Rourke (1988), future research may provide physiological evidence for his theory and therefore add significant substance for his conclusions.

The general findings of this study should also be interpreted with caution as children with a history of premature birthweight also demonstrate a variety of medical complications associated with preterm birth that have been selectively implicated in a number of deficits related to outcome, as noted in the literature review. The most prominent and well researched medical complications leading to adverse developmental outcome include respiratory distress, hypoxia and intraventricular hemorrhage and therefore, it is unlikely that low birthweight alone contributes to subsequent developmental deficits. Despite the fact that children born prematurely appear to be at greater risk for learning and neuro-developmental disorders at school age, it is difficult to identify any single factor that contributes to eventual outcome as this risk may reflect CNS injury from associated complications and/or insult referable to premature birth itself. All of these factors including SES, may therefore be contributing in varying degrees to eventual outcome implicating an interactive or dynamic model of development.

On the other hand, as noted in the current study, significant correlations between lower birthweight of the Prematures and the above variables were noted suggesting that these children appear to be more at risk for developing a host of neuro-behavioral, academic, and social-emotional deficits. This is not surprising as birthweight has been found to be a better predictor of neuro-developmental outcome than many medical complications in a number of recent studies (Landry, Fletcher, Denson, & Chapieski, 1993; Byrne, Ellsworth, Vinecer, Allen, & Stinson, 1993). This is particularly significant for children born with very low birthweight (<1500 grams). There is increasing evidence that the survival rate for these Prematures is increasing by approximately 10% per decade and that the age of viability is moving in a downward direction with smaller and younger Prematures surviving outside the natural environment of the womb. As a direct consequence of advances in neonatal medicine, the mortality rate for this subgroup has decreased significantly as many more neonates with very low birthweight survive. This has been met with positive reviews by some researchers since many of these children would not have survived even thirty years ago. However, survival rates versus quality of life thereafter are not distributed on the same continuum. In many cases children with lower birthweight and younger gestational ages appear to be more at risk for developmental and/or neuro-cognitive deficits as shown in the literature review. In many cases, these children may not display the more overt deficits associated with VLBW historically. However, more subtle deficits may still be prominent among these children as suggested by the current and previous research. There is every reason to believe that this population of VLBW Prematures is increasing and as the age of viability drops, society may again see a resurgence of more overt deficits such as cerebral palsy or other "hard" neuro-behavioral disorders that were common in the 1960's to 1970's simply due to the fact that more medical complications, such as a 40% to 50% co-occurrence of intraventricular hemorrhage, are associated with these Prematures. Further research in this area is vital particularly with respect to more subtle deficits such as Learning Disabilities and specific brain-behavior connections which can be accomplished at an interdisciplinary level and through neuropsychological assessment procedures as this approach has been found to be most valuable in current research.

What is clearly evident from both early and current research is that among surviving Prematures, there appears to be an increased demand for diagnostic, educational and rehabilitation services as these children frequently display a host of neuro-cognitive, learning and behavioral deficits. With respect to one of the most important institutions that they may encounter in their lifespan, these children are also found to be over-represented in special education settings or require special learning assistance. There is also a good likelihood that these children would have or will require the services of psychologists as well as other professionals in the health care and educational fields. The need for current clinical data investigating more specific neuropsychological processes among subgroups of children who appear to be at risk is underscored by some researchers such as Hynd and Willis (1988), and Rourke (1991b), who have predicted that the specific study of "at risk" groups will be a major trend in human neuropsychology in the 1990's. It is hoped that this study is a step in the right direction as further and perhaps more detailed longitudinal research is required particularly in the arena of Learning Disabilities; a handicapping condition affecting as many as one third of all children.

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Appendix

During the course of the study, it became increasingly apparent that each child and family presented unique characteristics or a particular set of deficits with respect to premature birth outcome. Some of these deserve attention on a qualitative level since quantitative analyses may only capture the essential or group features of individuals and therefore others may miss the more subtle aspects of problems that these children often display. In the case of children with Fetal Alcohol Syndrome for example, four children (13%) within the Premature Group were identified with FAS and in each case a distinctive pattern of dysfunction emerged which was not readily observable among other Premature children. This included global intellectual deficits, academic underachievement, poor eye-hand coordination, and globally depressed performance on the HRNB-C including poor performance on the motor tests of the HRNB-C. This pattern was also observed in children with Cerebral Palsy (2 Prematures = 6.3%). In addition, these two groups of children were also observed to have many features of Attention Deficit Disorder (ADD) including the Hyperactivity component (ADD-H), including other more subtle behavioral deficits that may not be severe enough to fit a category on the SIDAC, yet still result in some degree of impairment at the classroom level or in their social life. These subtleties could not be detected in group comparisons, however, these features are frequently representative of both these groups of disorders in the literature.

Qualitative analysis at the family level also resulted significant observations that could not be summarized quantitatively. For example, it was observed that the families of these children often faced significant hardship in dealing with the original traumatic events following preterm birth, in addition to trying to cope with the behavioral manifestations that these children displayed latter in life. In fact, it was not unusual for both couples to separate or divorce following the birth of a premature child and particularly if that child evidenced obvious developmental problems. The more subtle effects of family dynamics as well as SES factors can therefore be better appreciated qualitatively during the interview and in observing the test behavior and performance of these children. At this level of inquiry, it may have been possible to elucidate more detailed comparisons between the groups of children on a case by case basis and perhaps develop a more complete picture of the strengths and weaknesses of this group of children that would be valuable for other clinicians to use.

An example of the difficulties often encountered by older prematures without obvious or handicapping conditions at birth, is perhaps best illustrated by a brief case study. This information could not be summarized quantitatively or analyzed statistically, however, cases such as the one below represent the modal pattern of performance of these children in daily life as well as in their educational environment. With respect to birth history, the case in point is a child who was born at 30 weeks gestation with a birthweight of 1900 grams. He did not have any significant medical complications but did require ventilation and incubation for approximately 3 weeks. His progress in the Neonatal Intensive Care Unit was rather smooth, considering his birthweight, and his parents were quite pleased with the outcome at the hospital. He was followed up by the hospital for an additional 2 year period in which it was observed that he had chronic lung and/or respiratory infections, including ear infections and many allergies. Developmentally, his speech and language skills were unremarkable, however, his motor skills were somewhat delayed, particularly with respect to fine motor coordination, balance, eye-hand control, and visual-spatial skills. He was unable to ride a 2 wheel bicycle by age 6 and was not able to tie his shoelaces by age 7. At play school, he did not appear to be well coordinated on the playground and did not enjoy climbing on the apparatus. He seemed to be easily distractible and was described by others as "hyperactive" and impulsive. By Kindergarten, he was having difficulty with number concepts however, his overall skills were rather average. By Grade 1, his teacher noted weak number concepts but developing reading skills and well developed oral language. By Grade 3, some difficulties in reading (phonetic) skills were identified and his mathematical skills were quite weak. However, since his language and memory skills seemed appropriate, he was never referred for psychological assessment or resource room assistance. By Grade 5 or 6, his mathematical skills were clearly deficient and he was also displaying difficulties in written output skills and was falling further behind in his work due to very slow writing or note-taking. Oral skills remained well developed however. More problems were being noted with attention and concentration however, he was no longer considered as "hyperactive" and therefore never referred for an evaluation in this regard. Based with the prospect of being retained or repeating his current grade, due to these "deficits", his parents insisted that some type of evaluation occur since they noticed that he was quite capable in other areas. After considerable pressure, the school officials decided to have a specialist (School Psychologist) evaluate his skills. He was administered a brief version of an intellectual measure suitable for his age (WISC-R), and it was determined that he has average IQ. By now his premature birth history had largely been forgotten including his relative difficulties in motoric functioning, poor mathematical skills, written language skills and attentional deficits. Full Scale IQ was mentioned in the brief report however, the statistical discrepancy in favor of the Verbal IQ was not discussed. Academic assessment was not provided since it was determined that his reading skills were largely appropriate for his age.

The resulting case conference with his parents indicated that he was quite capable intellectually but that he needed to improve his "attitude" toward his school work. Motivation strategies were suggested in addition to counselling to improve his self-esteem. Several years went by without much change to this child's deficient skill level and he was soon facing a significant change to this academic program in High School with an emphasis on vocations. In short, the underlying strengths and weaknesses in this child's general functioning were never clearly identified until a comprehensive neuropsychological assessment was conducted at age 12.

This assessment clearly identified deficits in mathematics, written output skills, eye-hand coordination, visual-spatial skills, attentional skills and organizational ability compared to other children his age. Depressive symptoms, anxiety, and low self-esteem were also indentified and specific suggestions were made regarding intervention. His parents were also notified of the pattern of deficits that are often observed among children with premature birth history and that these seemingly diverse set of problems were also noted among other children with similar history. The parents and teachers were able to finally understand the nature of this child's difficulties and provide a suitable learning environment for him.

While cases such as this are frequently encountered in clinical and educational settings, they are often poorly understood since the pattern of difficulties that these children display are not well recognized. Inadequate screening procedures would also add to this confusion and may even contribute to inappropriate remediation strategies or in some cases, not lead to further evaluation which clearly would be indicated. The importance of applying the results of quantitative research to individual cases is underscored by the qualitative information discussed above. Only through greater understanding of the needs of these children, can parents, clinicians and educators be prepared to meet the demands of the future.