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NEUROBEHAVIOR OF PRETERM AND FULLTERM NEWBORNS: ITS RELATIONSHIP TO INTELLIGENCE AT 10 YEARS OF AGE

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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ABSTRACT

The relationship of infants' neurobehavior at birth and their intelligence at 10 years old was investigated in this study. Secondary data analyses used data from the original studies in Harrison (1988) and Harrison, Magill-Evans, Van der Zalm and Holdgrafer (1999). A total of 44 infants (23 full term and 21 preterm infants) were in the study. Healthy preterm and full term infants' neurobehaviors were assessed using the Brazelton Neonatal Assessment Scale (NBAS) at birth. Intelligence of these children at 10 years old was measured by the Wechsler Intelligence Scale for Children-Third edition (WISC-III). Infants' Regulation of state cluster scores on the NBAS were significantly correlated with their full scale IQ and performance IQ at 10 years of age. The Regulation of state accounted for 10 % of the variance in the full scale IQ and performance IQ scores. Children with abnormal state scores at birth had significantly lower scores than children in the normal group. The predictive validities of the NBAS and the Regulation of state cluster score in detecting healthy preterm infant at-risk for cognitive development (FSIQ $\leq$ 85) at 10 years of age were not satisfactory. The difficulties of predicting at-risk infants at early age were discussed.

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CHAPTER I
INTRODUCTION

Problem statement

Advances in medical technology are allowing younger and smaller infants to survive with fewer major disabilities. Some long-term follow-up studies have reported delays in cognitive performance in low birth weight infants until at least six years of age (Dunn et al., 1980; Lee & Barratt, 1993). Others have reported significantly lower IQ at eight years (McCarton, Bennett, McCormick & Meinert, 1997) and 10 years of age (Harrison, Magill-Evans, Van der Zalm & Holdgrafer, 1999), but with scores still within the normal range. Other studies have reported that there are no differences in the IQ scores for heavier preterm infants (birth weight <2500grams) and full term infants (Wallace, Escalona, McCarton-Daum & Vaughan, 1982). Children born prematurely with very low birth weight (<1500grams) often have lower IQ's along with learning, motor, emotional, social and behavioral problems in later development (Aylward, Pfeiffer, Wright, & Verhulst, 1989; Francis-Williams & Davis, 1974; Pharoah, Stevenson, & Cooke, 1994; Saigal, 1990; Sommerfelt, Markestad, & Ellertsen, 1998; Waber & McCormick, 1995).

Occupational therapists provide intervention in the neonatal intensive care unit (NICU). There are 45 neonatal therapists who have specialized in this area in Canada. Another 324 occupational therapists provide services to neonates in Canada (Canadian Association of Occupational Therapists [CAOT], 1999). Moreover, many pediatric occupational therapists work in follow-up clinics for high-risk infants in Canada and the United States and many high-risk infants were born prematurely. The role of the occupational therapist is to foster the infant's optimal occupational performance which includes neurobehavioral organization, sensory and motor processes and daily life activities in self-care, productivity and leisure (American Occupational Therapy Association [AOTA], 1993). Thus, occupational therapists need to understand the long-term implications of neurobehavioral organization early in life.

The synactive theory of development (Als, 1982) provides a framework for occupational therapists to meet the developmental needs of preterm infants and their families. Individual infant's neurobehaviors indicating stress or adaptation serve as guidelines for modifying caregiving practices by health care professionals and families. Neurobehavioral organization encompasses central nervous system (CNS) function and maturation as infants interact with parents, other caregivers, and their environment. By assessing neurobehavioral organization, one becomes sensitive to the complex dynamics of infant behavior, physiological status and infant attempts at self-regulatory strategies (Miller & Quinn-Hurst, 1994). Current neurobehavioral assessments such as the Brazelton Neonatal Assessment Scale (NBAS) allow clinicians to measure change and maturation in preterm infants so as to identify and explain infant behavior. Therapists can design individualized developmental supportive care plans for preterm infants based on the information gained from a neurobehavioral assessment.

Occupational therapists have a role in assessing and evaluating the neurobehaviors of the newborns in the NICU. An infant's neurobehavioral organization is influenced by both CNS function and maturation (Miller & Quinn-Hurst, 1994). Preterm infants have a lower threshold for sensory input. The process of a routine neurological assessment can stress the premature infant as indicated by significant increases in heart rate (Als, 1986; Sweeney, 1986; Vergara, 1992). Knowing that the handling procedure in some assessments will induce stress to the infants, the occupational therapist must consider the purpose of the assessment. The cost to the infant must be weighed against the value of the information gained. Information from neurobehavioral assessment can be used to suggest environmental modifications and caregiving to minimize the infant's stress (Vergara & Angley, 1992). It is important to identify the significant components of neurobehavioral assessments that will have a high predictive value for later development. Developmentally supportive care plans of routine caregiving can be generated after assessment of neurobehavioral organization and identification for the most appropriate infants for the care plans (Tribotti & Stein, 1992).

Early identification of infants at neurodevelopmental risk is essential so that intervention programs may begin without delay to enhance the functioning of these children (Infant Health and Development Program, 1990; Ramey et al., 1992). Early developmental intervention beginning in the NICU has been shown to be effective in improving the developmental outcome of premature infants (Als, 1997; Blanchard, 1991; Einarsson-Backes, Deitz, Price, Glass & Hays, 1994; Resnick, Eyler, Nelson, Eitzman, & Bucciarelli, 1987). Intensive intervention programs are costly if provided for all NICU survivors. The cost effectiveness of these programs could be improved if implementation is targeted to the most at-risk population (McCormick, 1989). Most of the research has been done to investigate the long term outcome of high risk preterm infants. Healthy preterm infants have lower IQ scores than the full term infants although their scores are within the normal range (Harrison et al., 1999; McCarton et al., 1997). However, there is limited research on the long-term follow up of healthy preterm infants and the need for healthy preterm infants, to receive early intervention and long-term follow up is unknown. Infants' neurobehavior as measured by neonatal neurobehavioral assessment may be an early predictor of intelligence in later childhood.

The aim of the current study was to determine whether infants' (healthy preterms and full term) neurobehaviour at birth as measured by the Brazelton Neonatal Behavioral Assessment Scale (NBAS) relate to intelligence of children when they are 10 years old. An observational and long-term follow-up study of healthy preterm and full term infants was carried out to evaluate the predictive value of neurobehavioral assessment in infancy for later developmental outcome.

Definition of terms

Healthy preterm infants: infants born with a gestational age less than 37 weeks at birth with no major or severe medical illness.

Healthy full term infants: infants born with a gestational age more than 37 weeks at birth with no major or severe medical illness.

Neurobehavior: the observable behaviors of a person, which are related to neurological status or to the nervous system. It may include habituation, orientation, motor performance, range of state, regulation of state, autonomic regulation and reflexes (Brazelton, 1984).

Intelligence: intelligence is a complex construct made up of verbal ability, practical problem solving and social competence (Sternberg & Detterman, 1986). Intelligence is the " capacity of the individual to act purposefully, to think rationally, and to deal effectively with his/her environment." (Wechsler, 1944, p.3).

CHAPTER II

LITERATURE REVIEW

Als (1982) proposed the synactive theory of development to explain newborn infants' behavioral organization and, specifically, the interactions of premature infants with the extrauterine environment. Newborn infants interact with the environment through behavioral subsystems: autonomic, motor, state, attention/interactive and self-regulation. The autonomic subsystem is behaviorally observable in respiration, color changes, tremulousness and visceral signals. The motor subsystem is observable in the posture, tone, and movement of an infant. The state organizational subsystem is observable in the range of states of consciousness of the infant, from sleeping to aroused and also in state transition. The attention/interactive subsystem is the infants' ability to be alert, to focus, and to respond to an external stimulus. The self-regulation subsystem is the infants' ability to balance and modulate other subsystems and become able to maintain a relatively stable and relaxed state even when exposed to a stressful situation.

These subsystems are mutually supportive and interactive (synactive) with each other. Subsystems develop in a hierarchical pattern with the autonomic subsystem as the most primitive and the core for the stability of the entire system. An infant must have stability in the hierarchically lower subsystems in order to be able to organize a behavior in a higher subsystem.

The maturation and integration of this behavioral system complex allow a healthy full-term infant to interact with the environment in an organized, smooth, and balanced way. The process is called neurobehavioral organization. When an infant, such as a preterm infant who lacks stability and control of a subsystem, is required to respond within that subsystem, signs of instability in the lower subsystems will appear. Thus, the neurobehaviours of the newborn reflect the maturation and integration of the neurobehavioral organization.

Because CNS function and maturation influence neurobehavioral organization, preterm infants are different from full term infants in their neurobehavioral performance. Aylward (1981) and Berg and Berg (1979) have suggested that behavioral states distinguish preterm from full term infants. Preterm infants were also differentiated from full term infants in three clusters (interactive processes, state organization and motor processes) of neonatal behavior (Brazelton, Als, Tronick & Lester, 1979; Lester, Emory, Hoffman, & Eitzman, 1976; Tynan, 1986). Healthy preterm infants showed significantly more autonomic, motor, state, attention and self-regulatory disorganization and required more examiner facilitation during the neurobehavioral assessment than full term newborns when preterm infants were assessed at term and 2 weeks post term (Als, Duffy, & McAnulty, 1988; Ferrari, Grosoli, Fontana, & Cavazzuti, 1983; Kurtzberg et al., 1979).

Findings suggested that early gestational age at birth, even following relatively normal intra-uterine development and with relatively good perinatal and neonatal conditions, is associated with more variable and disorganized neurobehavioral organization when the expected term of pregnancy is reached than is observed among healthy full term infants (Ferrari et al., 1983). These differences are related to immaturity and not social class (Als et al., 1988). The immaturity of the brain when exposed to the sensory environment of the intensive care unit and the extrauterine environment may cause the differences in early behavioral functioning in healthy preterm and full-term newborns (Duffy, Mower, Jensen, & Als, 1984). Immaturity of preterm infant's nervous system and different degrees of adaptive readiness of various subsystems appear to result in state disorganization. These conditions are associated with a lower functional and structural coherence or integrity within the CNS (Gardner & Karmel, 1983).

Majnemer, Brownstein, Kadenoff and Shevell's study (1992) found that preterm infants showed significantly poorer responses towards the auditory and visual stimuli than full term infants, but there were only a few differences in the reflexive items. They stated that the processing capability of infants appears to mature on an intrinsically programmed time and environment-independent pathway, with respect to reflexive elements (Majnemer et al., 1992). Preterm infants' scores relating to motor development and visual orientation approached the median range for full term infants by 40 weeks gestational age (Paludetto et al., 1982).

Stability and continuity in infants' neurobehavioral development is important to test if these behaviors are to be used in predicting later intelligence. Preterm infants were studied once a week longitudinally from 32 weeks gestational age to term (Korner et al., 1989). Neurobehavior of the preterm infants showed significant developmental gains with age and significant individual stability of performance over time. Preterm infants were in a stage of neurobiological development in which no major developmental discontinuities occurred.

Neurobehavior of normal preterm and full term newborns was reliable in grouping of infants into low threshold and easily disorganized babies; moderately well-modulated babies; and well-modulated babies (Als, Duffy, McAnulty & Badian, 1989). Behavioral organization predicted neuropsychological functioning at 5 years, with the low threshold reactive newborns showing much greater difficulties in cognitive development (spatial organization, attentional capacity and sequential processing). Als (1986) also reported that the low threshold, easily disorganized neonates were at greater risk for later organizational difficulties than the well modulated stable infants when they were reevaluated at nine months and five years of age. Infant habituation which reflects information processing or the mental activity to encode, register, store and retrieve information (Zelazo & Weiss, 1990), may predict later cognitive outcome for full term newborns (Dougherty & Haith, 1997; Colombo, Mitchell, Coldren, & Freeseman, 1991; Rose, Feldman, & Wallace, 1992). Prifiteria, Weiss and Saklofske (1998) suggested that a weakness in the speed of processing may affect higher order cognitive functioning such as learning which involves routine (e.g. reading) and complex (e.g. reasoning) information processing.

Although previous studies suggested that preterm infants are more variable in their neurobehavioral performance than the full term infants, neurobehaviors appear to have a predictive value in the later intellectual development in the preterm infants. Rose and Wallace (1985) studied 35 preterm infants and found that visual recognition memory at 6 months accounted for 28% to 43% of variance in their intelligence at 6 years as measured by the Wechsler Intelligence Scale for Children-Revised edition (WISC-R). Characteristics of preterm infants such as total fixation time and proportion of time in quiet sleep accounted for 30% of the variance in their full scale IQ (FSIQ) score at 8 and 12 years of age (Sigman, Cohen, Beckwith, Asarnow & Parmelee, 1992). In WISC-III (Wechsler, 1991), the Coding and Symbol Searching subtests of the performance IQ (PIQ) are measures of the rapidity with which a student can process simple or routine information without making errors. Correlations of the PIQ with neuropsychological tests which measure perceptual organization and processing speed ranged from .36 to .64 which is higher than verbal or full scale IQ (Wechsler, 1991). The neurobehavioral organization of the neonate may affect his/her information processing ability and reflected in the PIQ. It is hypothesized that some neurobehaviors (motor performance, range of state, regulation of state and autonomic regulation) are better predictors of the PIQ than the FSIQ.

The stability of infants' state or state organization over time may predict later development (Colombo & Horowitz, 1987). A curvilinear relationship between infants' state and visual attentiveness has been reported (Giacoman, 1971; Korner, 1972). State variables may reflect the postnatal refinement of the CNS, and changes in state organization could indicate the speed or status of CNS development itself (Colombo & Horowitz, 1987), which can be studied by behavioral and/or electrophysiological procedures (Prechtl, 1977; Thoman, Korner, & Kraemer, 1976). Tynan (1986) carried out multiple state observations on 25 neonates in the intensive care unit. He found that less stable profiles across the multiple observations were predictive of various severe medical conditions and infant mortality 10 weeks later. Infants who exhibited extreme instability of states across the multiple observations experienced developmental delays and/or severe medical problems at 6 and 60 months (Thoman, Denenberg, Sievel, Ziedner & Becker, 1981). Infants' control of state and state maturation is a pre-condition for the development of their information processing abilities (Colombo & Horowitz, 1987). According to the synactive theory of development (Als, 1982), the disorganized infant may have difficulties in stabilizing his/her state and this is related to later developmental difficulties.

Several studies have examined the predictive value of neonatal neurobehavioral examinations in healthy and at-risk newborns for later cognitive development (Als, 1986; Lipkin & Altshuler, 1994; Majnemer, Rosenblatt & Riley, 1994; Tronick & Brazelton, 1975; Wallace, Rose, McCarton, Kurtzberg, & Vaughan, 1995). Children with abnormal neonatal neurobehavioral assessment demonstrate developmental difficulties by three years or age but not in the first year of life (Majnemer et al., 1994). Thus, neonatal neurobehavioral examination appears to best predict difficulties in more advanced skills, which are manifest only in later development.

The Brazelton Neonatal Behavioral Assessment Scale (NBAS) (Brazelton, 1984) is used to assess infant's neurobehaviours at birth in seven areas including habituation, orientation, motor performance, range of state, regulation of state, autonomic regulation and reflexes. Brazelton and his associates believed that the examination brought out the most complex and integrated central nervous system functioning in the newborns. The NBAS was originally developed to describe the integration and separate functioning of the interactive, motoric, state and autonomic systems in the newborn (Als, 1997; Brazelton, Nugent & Lester, 1987). The newborns' use of 'states' is a reflection of both internal organization and the ability to control reactions to external stimuli (Brazelton, 1983). The examiner can identify the infants' organizational processes which are already relatively stable or overloaded. The neonates' capacity to manage and overcome the physiological demands of the assessment period in order to attend, to differentiate, and to habituate to the complex stimuli of an examiner's maneuvers may be an important predictor of his future CNS organization (Brazelton, 1983). Thus, the study of the neonates' process of neurobehavioral organization may predict later development. However, Cherkes-Julkowski (1998) suggested that prediction is difficult for children who are born only a short period before full term and weighed more than 1500 grams. These children are most likely to be mildly impaired and have minimal brain dysfunction (e.g., learning difficulties, attention deficit disorders).

Many studies have used the NBAS to compare the behaviors of preterm and full term infants. Preterm infants have exhibited differences in behavior and abnormal reflexes, and generally have a lower total score than full term infants (Lester, Garcia-Coll, Valcarcel, Hoffman & Brazelton, 1986; Lester et al., 1990; Myers et al., 1992). Malik and colleagues (1993) studied preterm and full term infants with the NBAS on days 3, 10 and 30, and assessed them by the Denver Developmental Screening Test (DDST) at 3 months of age. Infants in the normal DDST group had significantly higher Habituation, Motor and Range of state scores than infants in the abnormal DDST group.

The relationship between neonatal neurobehavior as measured by the NBAS and later developmental outcome has been studied (Anders, Keeners & Kraemer, 1985; Malik et al., 1993; Moss, Colombo, Mitchell & Horowitz, 1988; Sostek & Anders, 1977; Risholm-Mothander, 1989; Sell, Hill, Poisson, Williams & Gaines, 1985; Tronick & Brazelton, 1975; Vaughn, Taraldson, Crichton & Egeland, 1980). Fifty-three newborns suspected of having neurological problems at 3 days of age were assessed using the NBAS and a routine neurological examination and they were followed to 7 years of age (Tronick & Brazelton, 1975). At 7 years of age, 15 children (28 %) were 'abnormal' in development as indicated by more than three neurological signs (e.g., motor interference, twitches, abnormal movements, poor speech and hyperactivity) and IQ of less than 90, or neurological signs of central nervous system damage; and 38 children were normal. The Brazelton Scales detected 80% (12 out of 15) of abnormal neonates which is comparable to the routine neurological examination. However, the NBAS correctly identified 76% of the normal infants at birth while the neurological examination only identified 20% of the normal infants. The lower false positive rate is because the NBAS elicits higher order functioning of the CNS, such as alertness, state organization and quality of movement, to predict later development. The longest follow up study using the NBAS was 7 years (Tronick & Brazelton, 1975) and the value of neonatal neurobehavioral assessment in predicting intelligence over 7 years is not known.

Some of the full term newborns' cluster scores from the NBAS have been reported to correlate significantly with children's later development. The State control dimension (Sostek & Anders, 1977), Autonomic stability (Kato, 1991) and the Motor organization cluster score (Anders et al., 1985; Kato, 1991; Sell et al., 1985) correlated with the Bayley mental performance at 10 weeks, 6, 9, 12 and 24 months (range from .33 to .49). Moreover, Kato (1991) reported that infants with higher 30-day Motor score of the NBAS had significantly higher scores on the McCarthy Scales of Children's Abilities (MSCA) at 36 months. However, these studies included healthy full term newborns only. Healthy full term neonates were tested on NBAS with Kansas Supplement (NBAS-K) on the second or third day of life (Moss et al., 1988). The Orientation cluster score did not predict visual discrimination at 3 months but the Motor ($\underline{r} = .39$) and Range of state clusters ($\underline{r} = .49$) were significantly correlated with visual discrimination.

Functional assessment of preterm newborns' visual attention and sleep organization showed a modest relation to IQ measured at 8 years old (Cohen, Parmelee, Beckwith & Sigman, 1986). The influences of motor organization and state variables on later cognitive development need to be studied further. Researchers using other neurobehavioral assessment tools (Lipkin & Altshuler, 1994) reported that infants' habituation (Rose & Wallace, 1985) as well as visual and auditory orientation (Cohen et al., 1986; Wallace et al., 1995) of preterm infants were related to later intelligence.

Summary of literature review

The synactive theory of development (Als, 1982) provides a framework for explaining the newborn's development in neurobehavioral organization. Previous studies suggested that there is stability and continuity in infant neurobehavioral development. The neurobehavior at birth for preterm and full term infants such as the consistency of state, habituation, visual fixation time and motor organization may predict intelligence in later childhood. Although there are some contradictory results in previous studies, differences may be due to sample selection, the assessment battery used and methodology.

Brazelton Neonatal Behavioral Assessment Scale (NBAS) has been used widely in clinical research work (Brazelton & Nugent, 1995). Previous research has reported that some clusters of neurobehaviors have a predictive value for later intellectual development of both preterm and full term infants. The total score and/or some of the cluster scores in the NBAS (Motor, Range of state, Regulation of state, Autonomic stability), and infants' Habituation and Orientation as measured by other neurobehavioral assessment batteries are related to later cognitive development. However, there are no follow up studies examining the relationship of infants' neurobehavior and intelligence beyond 7 years of age.

It was hypothesized that the neurobehavior of newborns might reflect the development of the information processing ability, and thus predict intellectual performance in later childhood which is important for learning. Infants with abnormal NBAS score might have lower FSIQ, VIQ and PIQ scores than infants with normal NBAS scores later in childhood. The predictive values, sensitivity and specificity of the NBAS should be examined further with long term follow up study beyond 7 years. Moreover, some of the cluster scores from the NBAS (except the reflexes cluster) might be better predictors than the NBAS total score in predicting the performance IQ in WISC-III.

Specific objectives

The purpose of this study was to examine the relationship of infants' (healthy preterms and full term) neurobehaviors at birth as measured by the Brazelton Neonatal Behavioral Assessment Scale (NBAS) and the intelligence of children when they were 10 years old. Research questions were:

1. Do infants with normal or abnormal NBAS scores at birth differ on full scale IQ (FSIQ), verbal IQ (VIQ) and performance IQ (PIQ) at 10 years of age?

It was expected that infants with abnormal NBAS scores at birth would have lower full scale IQ (FSIQ), verbal IQ (VIQ) and performance IQ (PIQ) than infants with normal NBAS when they were 10 years of age.

2. What are the positive and negative predictive values, sensitivity, and specificity of the Brazelton Neonatal Behavioral Assessment Scale (NBAS) in detecting preterm infants at-risk for cognitive delay at 10 years of age?
3. Which cluster scores (Habituation, Orientation, Motor, Ranges of state, Regulation of state and/or Autonomic stability) from the NBAS are the best predictors of performance IQ at 10 years of age?

It was expected that the Motor, Ranges of state, Regulation of state and Autonomic stability cluster scores would be most highly correlated based on the literature.

CHAPTER III

METHOD OF INVESTIGATION

Participants

Children for this study were part of a longitudinal study of healthy full term and preterm infants' mother-infant interaction by Harrison (1988). As preterm infants showed more unpredictable and variable neurobehaviors, the inclusion of preterm and full term infants increases the variability of NBAS scores, allowing better opportunities to examine relationships between dependent and independent variables.

The original sample size was 62 (30 preterm and 32 full term infants) when the study started in 1986 and was recruited from a large urban hospital in Alberta. At the time of recruitment, all families were two parent families, White (except one mother was Oriental and one father was Black), English speaking, and residing in Edmonton or within a one-hour drive. The preterm infants had a gestational age at birth less than 37 weeks as assessed by the Dubowitz scale (Dubowitz, Dubowitz, & Goldberg, 1970). None of the preterm infants had significant medical problems other than prematurity and they met the following criteria: a singleton birth, birth weight appropriate for gestational age, no history of seizures, no congenital malformations, and able to breath without the use of a respirator by 7 days of age. Healthy preterm infants were selected to reduce the possibility that differences in infant behavior might result from medical complications rather than prematurity alone. Healthy full term infants were also selected according to the above criteria along with a gestational age at birth of 37 weeks or more. All families were in the middle or working class and thus environment was expected to have a similar effect on their development. There were more males in the preterm group than in the full term group as gender was not used for matching.

Forty-four out of 62 families could be located and agreed to participate in a study of preterm and full term infants' development in cognition and language 10 years later (Harrison et al., 1999). Eighteen children (9 born preterm and 9 born full term) could not be located and dropped out of the study. All the participants in Harrison et al. (1999) study are included in the current study. A multivariate analysis of variance (MANOVA) was conducted. There were no significant differences between families who remained in the study and those who dropped out of the study, in terms of children's gestational age at birth, birth weight, NBAS total score, mother's and father's education and family socioeconomic status (SES), as measured by the Hollingshead-4 factor index, F (6,55) = 1.08, p = .39 (see Table 3.1). Therefore, despite attrition, the sample remained unchanged in terms of demographic variables.

The participants were 44 children of whom 21 children were born preterm and 23 were born fullterm. Two preterm infants required respiratory support for 24 to 48 hours and one preterm infant was on a respirator for less than 24 hours. Demographic information for the parents and children born preterm and fullterm were also compared using a MANOVA and there were significant differences, F (6, 37) = 22.34, p < .001 (see Table 3.2). Preterm infants had a lower birth weight (range from 1250 to 2900 grams) than full term infants (range from 2860 to 4640 grams) (F (1,42) = 98.52, p < .001). Preterm infants were gestationally younger (range from 27 to 36 weeks) at the time of birth than the full term infants (range from 37 to 42 weeks), F (1,42) = 108.83, p < .001 and children were different in their age at the 10 year assessment, F (1,42) =8.5, p = .006.

Table 3.1

Comparison of information collected at the child's birth for families in the study (n=44) and those who dropped out (n=18)

	In the study (n = 44)	Dropped out (n = 18)
Children	M (SD)	M (SD)
Gestational age at birth (weeks)	36.6 (3.6)	35.9 (3.2)
Birth weight (grams)	2822.4 (876.2)	2838.3 (799.8)
NBAS total score	113.1 (20.5)	115.9 (18.3)
Parents		
Mother's education (yrs.)	13.1 (2.2)	12.6 (2.3)
Father's education (yrs.)	12.8 (1.9)	13.1 (2.7)
Family socioeconomic status (Hollingshead-4 factor index)	37.2 (10.2)	39.4 (12.8)

Table 3.2

Demographic information for mothers, fathers, and children (N=44) at 10 year of age

	Total	Preterm	Fullterm
	(n = 44)	(n = 21)	(n = 23)
Children	M (SD)	M (SD)	M (SD)
Gestational age at birth (weeks)*	36.6 (3.6)	33.4 (2.3)	39.4 (1.4)
Birth weight (grams)*	2822.4 (876.2)	2063.3 (477.0)	3515.4 (491.6)
Age at 10 year assessment (months)	120.3 (1.9)	121.1 (2.4)	119.6 (0.9)
Males (%)	54.5	71.4	39.1
Parents			
Mother's age (yrs.)	37.4 (4.8)	36.6 (5.4)	38.1(4.1)
Father's age (yrs.)	39.5 (5.3)	37.9 (5.2)	40.9 (5.0)
Mother's education at 10 year (yrs.)	13.7 (2.2)	13.7 (5.2)[a]	13.7 (1.8)
Father's education at 10 year (yrs.)	13.2 (2.0)	13.0 (2.1)[b]	13.4 (2.0)
Family socioeconomic status (Hollingshead-4 factor index)	39.5 (9.7)	39.3 (10.3)	39.7 (9.3)

*$p < .001$

a. n = 20

b. n = 19

There were no significant differences for children and parent's demographic information in terms of mother's and father's age and family SES. Mother's and father's education at 10 years were compared using t-tests due to missing data and there were no significant differences. There were more males in the preterm group than in the fullterm group as determined by the chi-square test (χ^2 (1, N = 44) = 4.08, p = .04).

Harrison (1988) conducted the study after ethical review by the Committee on Human Research at the University of Alberta and by the Clinical Investigation Committee of the Royal Alexander Hospital from which the sample was recruited. Both parents of the infant signed the consent form. Harrison et al. (1999) also received ethical approval from the University Ethical Review committee and consent was obtained from both parents and their children to conduct the study at 10 years of age. This study was approved by the Health Research Ethics Board in 1999.

Study design

This study was a secondary data analysis with data abstracted from the Harrison (1988) and Harrison et al. (1999) studies. Both studies were observational. Healthy preterm and full term infants' neurobehaviors were assessed using the Brazelton Neonatal Assessment Scale (NBAS score) at birth. Intelligence of these children at 10 years of age was measured by the Wechsler Intelligence Scale for Children-Third edition (WISC-III) (Wechsler, 1991).

Data collection

Birth status information was available from Harrison's study (1988). Infants' medical records included gestational age at birth, birth weight and gender. Parents were interviewed and they provided information on family's social class (according to Hollingshead 4-factor index [1975]), mother's age and education and father's age and education.

The Brazelton Neonatal Behavioral Assessment Scale was administered prior to the infants' discharge from the hospital. Assessment was done on the third or fourth day after birth for full term infants. For preterm infants, the assessment was completed at 37 to 39 weeks gestational age depending on the time of discharge. By 37 to 39 weeks gestational age, preterm infants would be considered developmentally the same as full term newborn infants. The NBAS (includes the 6 clusters) was used and the assessment took about 30 minutes.

The investigator who administered NBAS was a registered nurse. She was well trained in the NBAS and reached the interrater reliability of .90 during training with an instructor from the Neonatal Behavior Assessment Scale reliability training center at the Child Development Unit, Children's Hospital Medical Center in Boston. Although the rater was not blind to the child's birth status, she was well trained and a high interrater reliability was achieved. The investigator also dictated observations into a voice-activated recorder during the assessment, scored the scale immediately after the assessment was completed and then reviewed the recorded tape in comparison to the assigned scores to ensure the reliability of the NBAS assessments was reinforced. The independent variables were the 6 cluster scores and the total score of the NBAS.

The Wechsler Intelligence Scale for Children-Third edition (WISC-III) (Wechsler, 1991) was administered in the child's home when the children were 10 years old. A research assistant was trained to administer the test by a certified psychologist. The research assistant was blind to the child's birth status and the research hypothesis. The administration took between 50 and 70 minutes. The dependent variables were the verbal IQ (VIQ), performance IQ (PIQ) and full scale IQ (FSIQ) scores of the WISC-III.

Measures

The Brazelton Neonatal Behavioral Assessment Scale (Brazelton, 1984). It is used to evaluate an infant's neurobehavioral response to the environment from age 3 days to 4 weeks. It is an observational scale with 28 behavioral items score (9-point scale) (see Appendix I for an example of one item). The reflexes items were not used in this study. Items were clustered into 6 areas: Habituation, Orientation, Motor, Ranges of state, Regulation of state, Autonomic stability (Lester, Als & Brazelton, 1982). The scale is designed for both clinical and research work (Brazelton, 1984; Brazelton & Nugent, 1995). It is useful to identify suspected neurological problems in neonatal behavior. Inter-rater reliability varies between .85 to .90 (Brazelton, 1984). Predictive value for detecting newborns with later abnormal developmental outcome was discussed earlier. The internal consistency (coefficient Alpha) ranged from .49 to .84 and the test-retest reliabilities (Day 3 to Day 4) ranged from .18 to .68 for the 6 clusters (Jacobson, Fein, Jacobson & Schwartz, 1984). Behaviors most basic to infants' physiological organizations such as habituation, motor performance, autonomic regulation and range of state have better test-retest reliabilities as these neurobehaviors are more stable than the other neurobehavior over time. The interactive behaviors such as orientation, regulation of state and consolablity have lower reliabilities as they vary more (Brazelton, 1983).

Wechsler Intelligence Scale for Children-Third edition (WISC-III) (Wechsler, 1991). The scale measures the intellectual abilities of children ages 6 to 16 years and 11 months old. The full scale IQ (FSIQ) includes 2 subscales: the verbal IQ (VIQ) and the performance IQ (PIQ). The verbal scale includes 5 subtests: information, similarities, arithmetic, vocabulary and comprehension subtests. The performance scale includes another 5 subtests: picture completion, coding, picture arrangement, block design and object assembly. The scale has been used widely in psychoeducational assessment, clinical and neuropsychological assessment and research (Prifiteria et al., 1998). The Canadian normative scores based on 1100 children were used in this study. Inter-rater reliability was .90. Test-retest reliability (the median retest interval was 23 days) for children ages 10 and 11 was .94 (VIQ), .88 (PIQ) and .95 (FSIQ). The internal consistency for children at age 10 was .93 (VIQ), .88 (PIQ) and .95 (FSIQ).

Statistical analysis

Demographic data such as infant's gestational age at birth, birth weight, mother's age, father's age, years of mother's and father's education, and family's social class was described by means and standard deviation. As gender is nominal data, percentage distribution was calculated and a chi-square analysis was done. Alpha level was set at .05 unless Bonferroni corrections were done.

The raw scores of the NBAS were recoded and the total NBAS scores and 6 cluster scores were derived according to Lester's method (Lester et al., 1982). The predictive value of the NBAS was assessed using cut off scores to classify infants as normal or abnormal. Cutoff scores have not been identified by NBAS developers or in the literature. The total NBAS score of 32 full term infants in Harrison (1988) study was normally distributed (see Figure 3.1) as indicated by Shapiro-Wilk's test of normality. Therefore their scores were used to establish the cut off score. This included the 23 full term infants in this study.

Question1. Do infants with normal or abnormal NBAS scores at birth differ on full scale IQ (FSIQ), verbal IQ (VIQ) and performance IQ (PIQ) at 10 years of age? The NBAS score (total score of the 28 behavioral items in NBAS) was the independent variable. All the participants (N=44) were divided into 2 groups: one group above the NBAS cut off score, and the other group below the NBAS cut off score. One cutoff score was derived using the procedures of Kurtzberg et al. (1979) in which the performance was considered abnormal if the infant scored below or equal to the 5^{th} percentile of the full term infants' scores. The percentiles equal to minus one (the 16^{th} percentile) and minus two (the 2^{nd} percentile) standard deviations (SD) were also utilized as cut off points also for classifying the normal and abnormal group (Anderson, 1990). The corresponding IQ scores: FSIQ, VIQ and PIQ were the dependent variables. T-tests with Bonferroni corrections were used for comparison between these 2 groups.

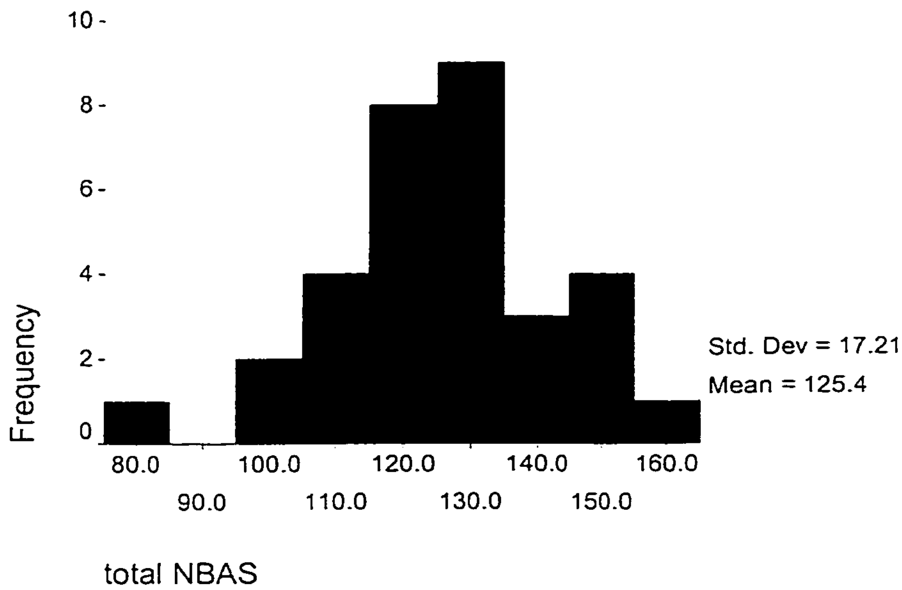

Figure 3.1 The total NBAS score distribution for full term infants in Harrison (1988) study (n=32).

Question 2. What are the positive and negative predictive values, sensitivity, and specificity of the Brazelton Neonatal Behavioral Assessment Scale (NBAS) in detecting preterm infants at-risk for cognitive delay at 10 years of age?

Classificational analyses were used to examine the relationship between the NBAS score and the WISC-III score. For the classificational analysis categorical group designations (normal or abnormal) applied. The cut off scores were established from the original sample in Harrison (1988), which included the 23 full term infants in this study. Only the preterm infants (n=21) were used to examine research question 2 to avoid inflation of the specificity values. The total NBAS scores of preterm infants and their corresponding FSIQ scores were used. A 2x2 contingency table was formed and the positive and negative predictive values, sensitivity, and specificity were derived. As the sample size was small, it was difficult to determine the predictive value, sensitivity, and specificity of the Brazelton Neonatal Behavioral Assessment Scale (NBAS).

Different cut off scores on the NBAS were used to determine which provided the most optimal combination of specificity and sensitivity (e.g., the 3rd percentile, the 10th percentile). For the WISC-III score, FSIQ less than or equal to 85 was used as the cut off score for the children at 10 years old according to procedures of Wallace et al. (1995). A FSIQ less than or equal to 85 is 1 SD below the mean and the score was used for classifying children who were in the below average range of functioning and at-risk for having learning problems.

	At risk (FSIQ $\leq$ 85)	Normal (FSIQ > 85)
Abnormal NBAS	a	b
Normal NBAS	c	d

Sensitivity is the proportion of infants classified as abnormal on the NBAS who are also identified as having lower FSIQ score at 10 years of age. It reflects the test's ability to correctly identify children at risk. Sensitivity = a/(a+c). Specificity is the proportion of infants classified as normal at birth who are still in the normal group at 10 years of age, and correctly identified by the cut-off. It reflects the test's ability to correctly identify children who are normal. Specificity = d/(d+b). Positive predictive value is the proportion of infants classified as abnormal at birth who were classified as at-risk at 10 years. Positive predictive value = a/(a+b). Negative predictive value is the proportion of infants classified as normal by the NBAS cut-off who were classified as normal at 10 years. Negative predictive value = d/(d+c).

It is essential to minimize the stress for the families due to misclassification. Effective allocation of resources can be enhanced, as it is expensive to provide early intervention program to all at-risk newborns when some typically developing children are included. However, one also wants to provide services for those who truly need it. Thus there needs to be a balance between each of these values.

Question 3. Which cluster scores from the NBAS are the best predictors of performance IQ at 10 years of age?

Six cluster scores of NBAS (Habituation, Orientation, Motor, Ranges of state, Regulation of state and Autonomic stability) for all the participants (N=44) were used as independent variables and the PIQ score was used as the dependent variable. Pearson correlations were used to determine the relationship between the variables. Cluster scores with non-significant correlations were dropped. Significant cluster scores were used in the stepwise regression to determine the amount of variance in intelligence explained by neurobehaviors.

CHAPTER IV

FINDINGS

The preterm group was compared with the full term group for the NBAS scores. Significant differences were found for the NBAS total score using a t-test (t(44) = 6.03, $p < .001$). A MANOVA was used to compare the NBAS cluster scores between the two groups (dependent variables: habituation, orientation, motor, range of state, regulation of state, autonomic stability cluster scores) and there were significant differences, F (6,37) = 12.60, $p < .001$. The univariate F-tests were significant for Habituation [F (1, 42) = 9.09, $p = .004$], Orientation [F (1, 42) = 6.84, $p = .012$], Motor [F (1, 42) = 36.86, $p < .001$] and Regulation of state cluster score [F (1, 42) = 38.78, $p < .001$) (see Table 4.1). As expected, children born full term had better NBAS scores than children born preterm.

This difference in some cluster scores might have been related to infant state. All the items in NBAS require the infant to perform the activity in a specific state as reactions are state-related. Preterm infants were more unstable in their state regulation and could not reach or maintain the specific state and thus specific items were not assessed. For example, preterm infant number 10 moved to state 4 (alert with a bright look) and 3 items (# 2, 3, 4) could not be administered with a score of 'zero' being given. The cluster scores where state might have had an influence were Habituation, Orientation, Motor and Regulation of state.

For the outcome at 10 years, t-tests with Bonferroni correction ($p < .02$) were used to compare the WISC-III performance between the two groups. There were no significant differences for the FSIQ and VIQ scores. Children born preterm had significantly lower

Table 4.1

Comparison of the NBAS scores of the preterm and full term infants at birth

	Total	Preterm	Full-term	
	(N = 44)	(n = 21)	(n = 23)	
NBAS	M (SD)	M (SD)	M (SD)	
Total score	113.1(20.5)	98.6 (12.5)	126.3 (17.3)	***
Habituation	16.1 (8.1)	12.5 (7.0)	19.3 (7.8)	**
Orientation	29.7 (9.5)	26.1 (6.9)	33.1 (10.4)	*
Motor	23.3 (4.1)	20.4 (2.9)	25.9 (3.2)	***
Range of state	13.4 (2.2)	13.2 (1.7)	13.5 (2.5)	
Regulation of state	19.2 (5.6)	15.1 (3.8)	22.8 (4.3)	***
Autonomic stability	10.8 (1.9)	10.3 (2.0)	11.2 (1.8)	

*$p < .05$, ** $p < .01$, *** $p < .001$

NBAS: Brazelton Neonatal Behavioral Assessment Scale, higher scores indicate optimal infant neurobehavior.

PIQ scores than children born full term ($\underline{t}$ (44) = 2.54, $\underline{p}$ = .015) (see Table 4.2). Among these children, three out of 23 (13%) children born full term and 6 out of 21(28.7%) children born preterm had an FSIQ $\leq$ 85. The mean FSIQ of the preterm infants (95.7) was similar to previous research where preterm infants with a birth weight $\leq$ 2500 grams had an FSIQ ranging from 92.7 to 95.5 (McCarton et al., 1997; Pharoah et al., 1994). Participants in this study were representative of the population of children born preterm.

There were more males in the preterm group than in the fullterm group (see Table 3.2). A MANOVA was used to examine the effect of gender and prematurity between the groups. There was no main effect for gender (dependent variables: habituation, orientation, motor, range of state, regulation of state, autonomic stability cluster scores, $\underline{F}$ (6,37) = 1.48, $\underline{p}$ = .21) and no interaction effect for gender and group, $\underline{F}$ (6,37) = 1.39, $\underline{p}$ = .25 on the NBAS performance. There was also no main effect for gender (dependent variables: verbal IQ, performance IQ, $\underline{F}$ (2,41) = 0.86, $\underline{p}$ = .43) and no interaction effect for gender and group, $\underline{F}$ (2,41) = .53, $\underline{p}$ = .59 on the WISC-III scores.

Research questions and findings

<u>Question 1. Do infants with abnormal NBAS scores at birth have a lower FSIQ, VIQ and PIQ scores than infants with normal NBAS scores when they are 10 years of age?</u>

There were no significant differences between the abnormal NBAS and normal NBAS group for the mean FSIQ, VIQ and PIQ scores at all the cutoff points (see Table 4.3 to 4.5). At the 2^{nd} percentile cut off, the abnormal NBAS group had non-significantly lower mean scores on all IQ scores than the normal NBAS group. At the other cut offs,

Table 4.2

Comparison of the IQ scores of children born preterm and full term at 10 years of age

	Total (N = 44)	Preterm (n = 21)	Full-term (n = 23)	
WISC III	M (SD)	M (SD)	M (SD)	
Full scale IQ	98.7 (15.3)	95.7 (18.0)	101.5 (12.0)	
Verbal IQ	99.1 (16.6)	98.4 (20.6)	99.7 (12.3)	
Performance IQ	99.2 (14.1)	93.9 (14.8)	104.0 (11.7)	*

*$p < .02$

WISC-III: Wechsler Intelligence scale for Children-Third Edition, Canadian normative values are used, M = 100, SD = 15.

Table 4.3

T-tests of IQ scores for comparison of infants with abnormal (n=7) and normal NBAS score (n=37) at 2nd percentile cut off

	Abnormal NBAS (n =7)	Normal NBAS (n =37)
WISC III	M (SD)	M (SD)
Full Scale IQ	95.3 (25.1)	99.4 (13.1)
Verbal IQ	97.6 (27.6)	99.3 (14.2)
Performance IQ	93.3 (19.8)	100.3 (12.8)

Table 4.4

T-tests of IQ scores for comparison of infants with abnormal (n=9) and normal NBAS score (n=35) at 5th percentile cut off

	Abnormal NBAS (n =9)	Normal NBAS (n =35)
WISC III	M (SD)	M (SD)
Full Scale IQ	98.6 (23.3)	98.8 (12.9)
Verbal IQ	100.1 (24.7)	98.8 (14.2)
Performance IQ	96.8 (19.5)	99.8 (12.7)

Table 4.5

T-tests of IQ scores for comparison of infants with abnormal (n=19) and normal NBAS score (n=25) at 16th percentile cut off

	Abnormal NBAS (n =19)	Normal NBAS (n =25)
WISC III	M (SD)	M (SD)
Full Scale IQ	98.7 (17.9)	98.8 (13.4)
Verbal IQ	100.9 (19.4)	97.7 (14.3)
Performance IQ	96.7 (16.0)	101.0 (12.5)

the abnormal NBAS group had similar or lower FSIQ and PIQ scores but slightly higher VIQ scores than those with normal NBAS scores.

Question 2. What are the positive and negative predictive values, sensitivity, and specificity of the Brazelton Neonatal Behavioral Assessment Scale (NBAS) in detecting preterm infants at-risk for cognitive delay at 10 years of age?

At 10 years of age, six out of twenty-one children (28.6%) born preterm had an IQ ≤ 85. At the 1st percentile, there was an empty cell in the contingency table and thus predictive values could not be calculated. The 2nd, 3rd, 5th, 10th and 16th percentiles on the NBAS were used for the classificational analysis. Sensitivity, specificity, positive predictive values and negative predictive values of NBAS were calculated and the values for the cutoff points are listed in Table 4.6. Using the 2nd percentile as cut off, the NBAS had the highest specificity but a low sensitivity and positive predictive values, and moderate negative predictive value. Increasing the cut off to 16th percentile improved the sensitivity but there was low specificity, as well as low positive and negative predictive values. Meisels (1988) suggested that both sensitivity and specificity should be no less than 80% for a conservative criterion. The positive predictive values for the 5 cutoff points ranged from 23.5% to 33% only and the negative predictive values ranged from 50% to 72%. The highest sensitivity value was obtained at the 16th percentile cut off.

Sensitivity values were low and the NBAS failed to detect the abnormal infants. Moreover, specificity values were low and the false positive rate was high; many infants were identified as having abnormal NBAS at birth but normal FSIQ in later childhood. It appeared that the preterm infants with a low NBAS score at birth might perform very

Table 4.6

Sensitivity, specificity, positive predictive value (+PV) and negative predictive value (-PV) of NBAS total score for at-risk versus normal classification (n=21)

Cut off	a cell (n)	b cell (n)	c cell (n)	d cell (n)	Sensitivity (%)	Specificity (%)	+PV (%)	-PV (%)
2nd	1	2	5	13	16.6	86.6	33.0	72.0
3rd	2	6	4	9	33.3	60.0	25.0	69.2
5th	2	6	4	9	33.3	60.0	25.0	69.2
10th	3	8	3	7	50.0	46.4	27.3	70.0
16th	4	13	2	2	66.6	20.0	23.5	50.0

well or very poorly on IQ tests at 10 years of age. Preterm infants' total NBAS score at birth was a poor predictor for their IQ at 10 years of age.

Question 3. Which cluster scores from the NBAS are the best predictors of performance IQ at 10 years of age ?

Two cluster scores from the NBAS, the Regulation of state cluster and the Motor cluster were significantly correlated with the PIQ score. These two predictor variables were retained for the regression analysis. Inter-correlations between the predictor variables and the IQ scores were also examined (see Table 4.7). The Motor cluster and the Regulation of state cluster were significantly correlated with each other. The Regulation of state cluster was also significantly correlated with the full scale IQ ($r = .35$) and verbal IQ scores ($r = .30$).

A stepwise regression was conducted and the Regulation of state and the Motor cluster were entered into the analysis. Only the Regulation of state cluster score (comprised of cuddliness, consolability, self-quieting and hand-to-mouth) was a significant predictor for the performance IQ score, accounting for 10% of the variance ($B = .88$, $SE\ B = .36$, $\beta = .35$, $p = .02$). The Regulation of state cluster score was also a significant predictor for the full scale IQ score, accounting for 10% of the variance ($B = .96$, $SE\ B = .39$, $\beta = .35$, $p = .02$). As expected, the cluster score was a better predictor than the total NBAS score.

In summary, infants with abnormal NBAS scores at birth did not differ from infants with normal NBAS scores in their IQ scores at 10 years of age. The total NBAS score did not discriminate infants at-risk for cognitive development from infants with

Table 4.7

Inter-correlations between NBAS scores and IQ scores of children at 10 years of age (N=44)

		1	2	3	4	5	6	7	8	9
1	Habituation	--								
2	Orientation	.42**	--							
3	Motor	.23	.46**	--						
4	Range of state	.02	.13	.15	--					
5	Regulation of state	.20	.30	.57**	.20	--				
6	Autonomic stability	-.26	.11	.48**	.14	.27	--			
7	Total NBAS score	.67**	.82**	.71**	.27	.63**	.23			
8	Full Scale IQ	-.17	-.15	.21	.16	.35*	.05	.02		
9	Verbal IQ	-.16	-.24	.10	.17	.30*	.01	-.06	.92**	--
10	Performance IQ	-.11	.04	.32*	.11	.35*	.10	.14	.87**	.61**

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

normal development. The sensitivity, specificity, positive and negative predictive values showed poor predictive validity for the NBAS. As the NBAS measured a wide range of neurobehavior, cluster scores may have a better relation with children's later IQ score. The Regulation of state cluster (1 out of 6 clusters) accounted for 10% of the variance in PIQ and FSIQ. According to the literature, the Regulation of state cluster was expected to be a better predictor than the total NBAS score for PIQ (Sostek & Anders, 1977; Vaughn et al., 1980). Therefore, secondary data analysis was done using the Regulation of state cluster to replace the total NBAS score and research questions 1 and 2 were reexamined.

The Regulation of state cluster score of the 32 full term infants in Harrison (1988) study was normally distributed (see Figure 4.1) as indicated by Shapiro-Wilk's test of normality. It was used as the standard to establish the cut off score. To reexamine research question 1, the 2nd, 5th and 16th percentiles on the State score were identified as the cut offs. Infants in the current study were then classified into the abnormal or normal State group. At the 2nd percentile cutoff, the abnormal State group (n=6) had significantly lower mean FSIQ ($\underline{t}$ (44) = 3.46, $\underline{p}$ = .001), VIQ ($\underline{t}$ (44) = 2.98, $\underline{p}$ = .005) and PIQ scores ($\underline{t}$ (44) = 3.24, $\underline{p}$ = .002) than the normal group (see Table 4.8 to 4.10). All of the 6 infants identified in the abnormal State group were born preterm. At the 5th and 16th percentile cut off points, the abnormal State group also had slightly lower scores than the normal State group, though the differences were not significant.

To reexamine research question 2, the 2nd, 3rd, 5th, 10th and 16th percentiles on the Regulation of state cluster score were used for the classificational analysis. Sensitivity, specificity, positive predictive values and negative predictive values of the Regulation of state score are listed in Table 4.11. The sensitivity, specificity, positive and negative

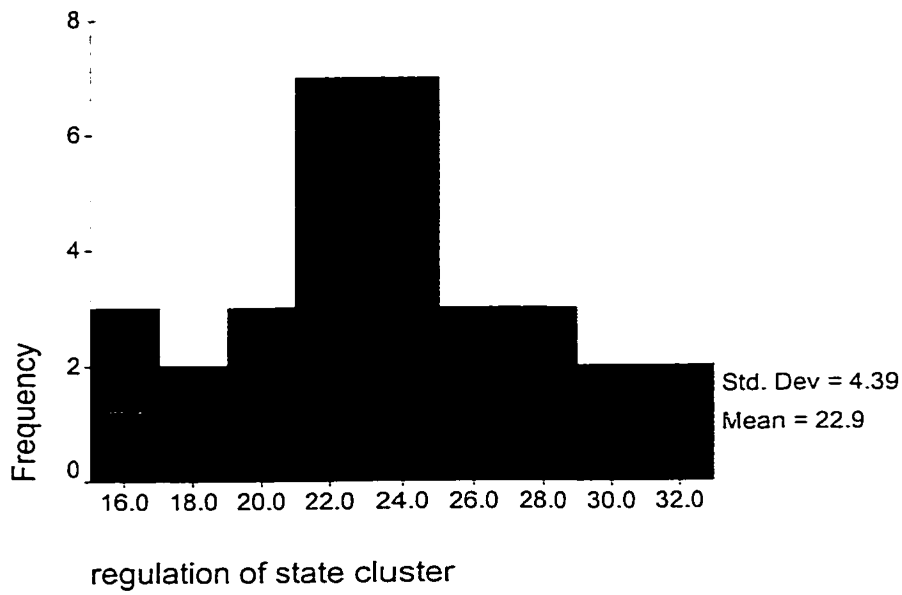

Figure 4.1 The Regulation of state cluster score distribution for full term infants in Harrison (1988) study (n=32).

Table 4.8

T-tests of IQ scores for comparison of infants with abnormal (n=6) and normal Regulation of state cluster score (n=38) at 2nd percentile cut off

	Abnormal State	Normal State
	(n =6)	(n =38)
WISC III	M (SD)	M (SD)
Full Scale IQ	80.8 (19.1)	101.6 (12.7)**
Verbal IQ	81.8 (22.5)	101.8 (14.0)*
Performance IQ	83.5 (13.9)	101.7 (12.6)*

* $p < .01$, ** $p < .001$

Table 4.9

T-tests of IQ scores for comparison of infants with abnormal (n=13) and normal Regulation of state cluster score (n=31) at 5th percentile cut off

	Abnormal State	Normal State
	(n =13)	(n =31)
WISC III	M (SD)	M (SD)
Full Scale IQ	95.5 (21.5)	100.1 (12.0)
Verbal IQ	96.5 (22.2)	100.1 (13.8)
Performance IQ	95.6 (18.2)	100.7 (12.0)

Table 4.10

T-tests of IQ scores for comparison of infants with abnormal (n=21) and normal Regulation of state cluster score (n=23) at 16th percentile cut off

	Abnormal State (n =21)	Normal State (n =23)
WISC III	M (SD)	M (SD)
Full Scale IQ	97.1 (18.1)	100.3 (12.4)
Verbal IQ	98.5 (19.6)	99.6 (13.6)
Performance IQ	96.5 (16.1)	101.7 (11.8)

Table 4.11

Sensitivity, specificity, positive predictive value (+PV) and negative predictive value (-PV) of Regulation of state cluster score for at-risk versus normal classification (n=21)

Cut off	a cell (n)	b cell (n)	c cell (n)	d cell (n)	Sensitivity (%)	Specificity (%)	+PV (%)	-PV (%)
2nd	3	3	3	12	50.0	80.0	50.0	80.0
3rd	4	5	2	10	66.6	66.6	44.4	83.0
5th	4	7	2	8	66.6	53.3	36.4	80.0
10th	5	12	1	3	83.3	20.0	29.4	75.0
16th	5	12	1	3	83.3	20.0	29.4	75.0

predictive values improved when the Regulation of state cluster score replaced the total NBAS score. The Regulation of state cluster score was a better predictor than the total NBAS score in detecting infants at-risk for later cognitive development at 10 years of age. However, the combination of the predictive values failed to provide a satisfactory cut off point. The positive predictive values for the cutoff points were low (ranged from 29.4% to 50%), and the negative predictive values were high (ranged from 75% to 81.3%). At the 2nd percentile cut off, specificity was high (80%) but sensitivity value was low (50%) and the Regulation of state cluster scores only detected 50% of the at-risk infants. At the 10th percentile cut off, sensitivity value was high (83.3%) but specificity value was low (20%) and the false positive rate was high. Many infants were identified as having abnormal state at birth but had normal FSIQ in later childhood.

Summary of findings

The Brazelton Neonatal Behavioral Assessment (NBAS) measures a wide variety of preterm and full term infants' neurobehavior at birth. The relationship of preterm and full term infants' NBAS score and their IQ scores at 10 years of age were examined. Findings in this study showed that preterm and full term infants in the abnormal NBAS group did not differ from the normal group in their IQ scores at 10 years of age. The predictive validity of total NBAS score in identifying healthy preterm infants at-risk for later cognitive development (FSIQ $\leq$ 85) was poor. As expected, the Regulation of state cluster score was a better discriminator and predictor than the total NBAS score in identifying at-risk infants. There were significant differences between the abnormal and normal state group using the 2nd percentile as a cut off. Preterm and full term infants' state score significantly correlated with their FSIQ and PIQ scores at 10 years of age. The

Regulation of state cluster score accounted for some variance in children's FSIQ and PIQ scores at 10 years of age. In evaluating the combination of the predictive values, sensitivity and specificity of the state score, there was not a single cut off point which was satisfactory. Using the Regulation of state cluster alone as a predictor, there was a high false positive rate, or misidentifying normal preterm infants as abnormal. The magnitude of the correlation (r = .35) and variance (10 %) accounted for the FSIQ and PIQ were significant but low. Thus the clinical significance was questionable. However, as there was a ten-year interval for the prediction, the magnitudes were not unexpected. The use of Regulation of state cluster score alone for clinical prediction of preterm infants at-risk in later cognitive development at 10 years of age was insufficient. The difficulties of predicting infants at-risk for later cognitive developments are discussed in the next chapter.

CHAPTER V

DISCUSSION

The purpose of this study was to examine the relationship of infants' (healthy preterm and full term) neurobehaviors at birth as measured by the Brazelton Neonatal Behavioral Assessment Scale (NBAS) and the intelligence of children when they were 10 years old. Findings in the study showed that the total NBAS score was not useful in identifying children at-risk for lower IQ scores, although the Regulation of state cluster score was more useful. Infants with abnormal state scores had significantly lower mean IQ scores than children in the normal group. Infant's Regulation of state cluster score was significantly correlated with full scale IQ and performance IQ ($r = .35$). It also accounted for 10% of the variance in full scale IQ and performance IQ at 10 years of age. As expected, the cluster score was a better predictor than the total NBAS score. Findings were congruent with those of previous studies, which found that the Regulation of state cluster correlated with children's cognitive development with similar correlational values (Sostek & Anders, 1977). In the following section, I will discuss why the Regulation of state cluster score was more useful than the total NBAS score, the relationship between the Regulation of state and IQ, the factors affecting the predictive validity of the NBAS and the use of the cut off point.

The total NBAS score was not as useful as the Regulation of state score in prediction of later cognitive development. There are several possible explanations for this finding. The NBAS assesses a wide variety of infants' neurobehaviors and not all the behaviors could be expected to predict children's later IQ. The match between the predicting assessment and the outcome construct enhances the predictive validity. Brazelton and colleagues (1987) suggested that the motor and autonomic clusters might predict future motor function better. Other clusters that indicate infants' internal regulation ability in interaction with environmental input such as the Regulation of state cluster score may correlate with their future cognitive performance. In the current study, children's IQ was the only outcome measure. The NBAS was not a strong predictor of this outcome, although it was a good predictor in the Tronick and Brazelton study (1975) in which children were defined as having 'abnormal' outcomes if they had cognitive, motor, neurological or speech deficits at age seven. Using multiple outcomes, the predictive validity for the NBAS was satisfactory: sensitivity (80%), specificity (76%), positive predictive value (57.1%) and negative predictive value (90.6%). Thus, the result in this study might have been related to the use of a single outcome measure.

The dynamic systems approach (Thelen, 1989; Thelen & Smith, 1994) provides an explanation for the limited amount of variance explained by the total NBAS scores. According to the theory, the CNS and the interaction of the participating subsystems influence motor skill, which results in development. Environment also plays an important role in development. Development is not linear, and infants or children with abnormalities may 'catch up' to normally developing infants spontaneously. The observation of neurobehaviors of infants only is not adequate to predict later childhood IQ. Neurobehavior is not simply the product of a single control system (e.g. the neuromotor system). Rather, neurobehavior and its developmental sequence are products of a complex interaction of multiple systems or constraints that affect the developing organism (e.g., muscle strength and tone, body mass, the peripheral and CNS, task demands, motivation, goals and intentions, developmental changes and environmental exposures) (Holt, 1997). Thus, within this approach, it would be necessary to consider other subsystems' effects on cognitive development. This information was not available in this study.

The state score was more useful than the total NBAS score in predicting children's later IQ. There are many reasons why the Regulation of state score has a stronger relationship. Two theories suggested the relationship of the Regulation of state cluster to IQ. According to the synactive theory (Als, 1982), newborn infants have five subsystems which interact with each other. If there is any instability in the self-regulation subsystem, then the lower subsystems will take over. The self-regulation subsystem maintains the infant in a stable and relaxed state when exposed to the environment. The NBAS measured the integrated behaviors of the infant's CNS, and these behaviors are state related. The Regulation of state cluster (comprised of cuddliness, consolability, self-quieting and hand-to-mouth) measured infants' coping abilities in state transitions and thus assessed the maturation of infants' self-regulation. According to the neuromaturational theory of motor development (Gesell, 1928; McGraw, 1945), the CNS controls motor development that is genetically determined. Thus, any deviance in infants' neurobehaviors may reflect permanent CNS pathology. As mentioned earlier, infants with mature self-regulation can interact with the environment and neurobehavioral organization occurs. In the current study, preterm or full term infants with CNS pathology might have been immature in self-regulation and showed neurobehavioral disorganization during interaction with the environment. Infants with neurobehavioral disorganization have difficulties in stabilizing their states and thus with cognitive development. The areas of cognitive development that may be affected include spatial organization, attentional capacity and sequential processing, all of which are measured by the performance IQ.

An infant having a low score in the Regulation of state cluster reflects possible immaturity in the self-regulation subsystem and neurobehavioral disorganization, which indicates impairment in the CNS and affects cognitive development. When the Regulation of state cluster score at the 2nd percentile cut off was used, infants with abnormal state scores had significantly lower IQ scores than infants with normal scores. These six infants were all born preterm. Preterm infants have poorer modulation of state transition than full terms (Als, 1991). In the current study, there were 10 (out of 21) preterm infants who scored zero on one of the Regulation of state items (item 17, consolability). This item requires an infant to cry for 15 seconds before the administration. Preterm infants seldom cry because they have difficulty coming to a crying state (Als et al., 1988), and therefore they obtained lower scores than the full term infants. Brazelton (1984) defined state 6, crying, as an intense crying which is difficult to break through with stimulation, and there is high motor activity. The presence of crying is a positive indicator of the infant's ability to self-regulate by shutting out offending and negative stimuli from the internal or external environment (Covington, 1990). Infants' use of states to modulate their responses to internal and external stimuli reflects their organizational potentials. State regulation in the neonatal period seems linked to later ability to attend to and process information and is reflected in their later IQ (Gorski, Lewkowicz & Huntington, 1987). Preterm infants had lower Regulation of state scores and the fact that they showed more neurobehavioral disorganization than the full term infants might indicate that preterm infants are at-risk for cognitive development. It also indicated that the Regulation of state cluster score was sensitive to variations in state, and state is related to IQ. Thus, the Regulation of state cluster score had a better predictive validity than the total NBAS score in identifying infants at-risk for cognitive development.

Predictive validity using either the total NBAS or the Regulation of state score is not clinically useful. The sensitivity, specificity and positive and negative predictive values improved when the Regulation of state cluster score replaced the total NBAS score. However, there was no clinically adequate combination of the four predictive values. The evaluation of predictive validity considers a combination of sensitivity, specificity and positive and negative predictive values. The sensitivity and specificity values provide information on how accurately the outcome of a group of infants was predicted by the NBAS. The positive and negative predictive values give the information of an individual infant's likelihood of being at-risk in cognitive delay at 10 years of age. The positive predictive value is the most clinically useful value.

At the 2^{nd} percentile cut off, the State score had a higher sensitivity value (50%) than the total NBAS score (16.6%), and both had the same specificity value (86.6%); the positive (50%) and negative predictive values (80%) also improved. Increasing the cut off to the 16^{th} percentile increased the sensitivity, and the state score still had a higher sensitivity value (83.3%) than the total NBAS score (66.6%). Both the state score and the total NBAS score had a low specificity (20%) and low positive predictive values (range from 23.5% to 29.4%). The combination of the predictive values failed to identify a satisfactory cut off point for the Regulation of state score. Many infants were identified as abnormal at birth but had normal FSIQ in later childhood. Although findings showed that infant's regulation of state accounted for some variance in later FSIQ and PIQ, the magnitude was low. Findings in the study did not support using the Regulation of state cluster alone for clinical prediction.

Accurate identification of infants at-risk for later cognitive development is difficult. The predictive validity of the NBAS was affected by the sample size, developmental profile of the preterm infants, time of assessment, use of a single NBAS assessment and one rater, and the prediction interval. First, if the prevalence rate for some developmental abnormalities in the general population is low, a large random sample is required for a classificational analysis to provide a stable estimate of specificity and sensitivity (Dunn, 1989; Miller, Lemerand, & Schouten, 1990). If a small sample size is used as in this study, a single subject's categorization as normal or abnormal will change the accuracy rate considerably (McCall, 1982). Six out of 21 (28.7%) healthy preterm infants were identified as at-risk according to the WISC-III results; thus, a single child could account for 16.7% of the sensitivity value. The sample for establishing the NBAS cutoff score was also small (n= 32 full term infants). Although the total NBAS scores were normally distributed, a larger sample size would have provided a more valid NBAS cut off score for the population and eliminated the sampling bias. A larger sample would also have limited the impact of a single subject.

Second, the predictive validity results may also be due to the way preterm infants develop. Drillien (1972) found that preterm infants develop transient dystonia or neuroabnormality, and they have less flexor muscle tone, more extended postures, prolonged retention of primitive reflexes and more variability than full term infants. Forty to 50% of the preterm infants had transiently abnormal neurologic signs in the first few months of life. Preterm infants with transient neuroabnormality would be identified as abnormal during the NBAS assessment, which was reflected in this study in that children born preterm had lower NBAS scores. However, the low scores in Regulation of state might have been influenced by the signs of transient neuroabnormality. The children that 'recovered' from the transient neuroabnormality would show more normal IQ scores at 10 years of age.

Third, the time of assessment also affects the predictive validity. There are large individual differences in children's development; the younger the child, the less reliable the predictions will be (Dunn, 1989; McCarthy, 1980). The NBAS is not alone in having this problem as other neonatal tests report high false positive rates, ranging from 50% to 80% (Allen & Capute, 1989; Bozynski et al., 1993; Dubowitz et al., 1984; Majnemer et al., 1994). Moreover, the Denver Developmental Screening Test and other standardized infant assessments have better predictive validity when used after two years of age (McCall, 1982). Thus, the use of the NBAS at birth to identify children at-risk for later delays is difficult.

Fourth, one single NBAS assessment and one examiner were used in this study. This may also affect the validity of the total NBAS score. Lester (1984) recommended using the cluster scores of three NBAS examinations in the first month of life to develop the recovery curves or profiles. The profile reflects an individual infant's recovery pattern after the stress of delivery and the coping capacity to assimilate early environmental stimulation (Brazelton et al., 1987). Full term and preterm infants' recovery curves significantly predicted and accounted for 42% to 63% of the variance in their mental outcomes at 18 months (Lester, 1984). The NBAS recovery curve profiles of the full term and preterm infants also had significant relationships with their Bayley Mental Development Index at 1 year, Stanford-Binet Scores at 3 years and McCarthy scores at 5 years (Nugent, Greene & Brazelton, 1987; Sepkoski, Hoffman & Brazelton, 1987). The recovery profiles of the infants may have better predictive value than using one single NBAS examination, though this has not been studied and certainly not over a period as long as in this study. Asch, Gleser and Steichen (1986), who examined the source of variance for repeated measures of the NBAS, suggested at least two test occasions and possibly two raters for clinical prediction. The same rater or rater pair should be used for the whole sample to reduce the systematic error due to rater, subject and occasion. The same rater was used for the whole sample in this study.

Fifth, the longer the prediction interval between the predictor and criterion assessment, the weaker the predictive validity; and the classificational accuracy also decreases over time (Bowerman & O'Connell, 1979). Other factors such as the environment and maturation might also influence the predictive validity. This study had a ten-year interval between the predictor and the criterion measures; thus, low predictive values for the NBAS were expected. The finding that infants' Regulation of state cluster score accounted for 10% of the variance for FSIQ and PIQ at 10 years of age is reasonable given the interval. The identification of at-risk infants at such an early age, with subtle developmental problems over such a long period of time (10 years) is difficult. When infants born prematurely were followed through school age, the deficits in their intelligence at earlier ages were greatly reduced in later years (Drillen, Thomson & Burgoyne, 1980; Robertson, Etches & Kyle, 1990).

The environment has the potential of minimizing or maximizing the early developmental difficulties and thus affecting the predictive validity. For infants with early perinatal complications such as prematurity who were raised in a middle-class home, with a stable family structure and with educated parents as in this study, there is limited relationship between perinatal complications and later intelligence. When children with similar complications were raised in a lower SES home, an unstable family situation, or with uneducated parents, they were more likely to suffer mental retardation and behavioral problems (Bradley et al., 1993; Guo, 1998; Magyary, Brandt, Hammond & Barnard, 1992; Molfese, DiLalla & Lovelace, 1996). There is an interaction of prematurity and SES on full scale IQ, verbal tests, academic achievement and attention; children born preterm with lower SES scored lowest on these measures (Ross, Lipper & Auld, 1991). Parental IQ is linked to children's IQ (Bouchard & McGue, 1981; Plomin, 1987; Scarr & Weinberg, 1987) and part of this link is mediated through the quality of home environment. Mothers with higher intelligence tend to provide more stimulation and support for their children, which contribute to children's higher IQ (Bradley et al., 1993; Watson, Kirby, Kelleher & Bradley, 1996). All the families in this study belonged to the working or middle class at the time of the infants' birth, and parents were well educated. There was no economic adversity in the environment for the at-risk infants.

The predictive validity of the NBAS may also be affected by the uncontrolled effects of the child's history (physical injury, parental stimulation, classroom experiences, clinical and educational interventions), maturation, and his/her environment, which is not necessarily constant over time (Miller et al., 1990). The sample had not been followed and assessed during the past 10 years for identification of other environmental factors. There was no evidence to support the environmental effects on children's cognitive development.

The use of cut off points also affects the predictive validity of the NBAS. Lichtenstein and Ireton (1991) reported that classificational analysis results depend on the use of a cutoff point to assign children to groups (normal and abnormal). The test developers have not developed any cut off point for the NBAS, and there was no normative study. Different cut off points were tried in this study to divide the infants into the normal and abnormal groups. The cut off point (2^{nd} percentile) used in this study may not generalize to other studies due to the small sample size and the selected sample. Moreover, children in the abnormal state group were all born preterm. This may be due to the fact that the cut off point was derived using the distribution of the full term infants' scores. In future work, it would be useful to establish a cut off point using the preterm infants' scores only, so that the low scores in state regulation can be more easily interpreted as reflecting neurobehavioral disorganization.

Both the NBAS and the WISC-III scores were scored continuously, and children with a wide range of abilities were then forced into the binary grouping (normal and abnormal). There is a potential for loss of important information about the individual' performance (Miller et al., 1990). Children with marginal performance may pass the assessment and be excluded from the early intervention, only to be identified when severe developmental problems arise later (Lichtenstein & Ireton, 1984). In the current study, six children born preterm had an FSIQ ≤ 85. Using the 2^{nd} percentile of the state score as the cut off, three infants were identified correctly by the NBAS as abnormal, having an FSIQ ≤ 85 at 10 years of age. However, the other 3 infants passed the NBAS, and they were missed. When the cutoff was increased to the 10th percentile, five children at-risk in cognitive development were identified, but many infants were misidentified as abnormal.

Adjusting the cutoff score influences the under and overreferral rates in opposite ways. As mentioned earlier, at the 2nd percentile cutoff, the state score had only moderate sensitivity (50%), and the NBAS underreferred at-risk children. At the 10th percentile, the specificity was low (20%), and it overreferred children who were not at-risk. Undereferrals deny a child's opportunity for an early intervention that may lead to a better outcome. Parents who were told that their children had no problem at an initial screening and were then later told that their child had developmental problems may be confused and disappointed (Meisels, 1988). Overreferrals imply unnecessary assessment and treatment and that may also increase parental anxieties. A good screening test must have both high sensitivity and specificity values, but the NBAS did not have a single cut off point that fulfilled the condition. Therefore, the Regulation of state cluster score could not be used alone as the clinical predictor.

Findings in the study showed that 6 out of 21 children born preterm were identified as at-risk (FSIQ $\leq$ 85). School problems were reported by parent questionnaires. All 6 children had had school problems since grade one, which still existed at 10 years of age. Intervention included extra help in the classroom with an aide, tutoring, full time remedial classes, a resource room, counseling, grade retention, special education and referral for rehabilitation in speech and other areas of development. The fact that these children from a healthy preterm sample went on to have school problems suggests there is a need to provide early developmental screening for healthy preterm infants who are not generally viewed as needing follow-up.

Limitations

There were some limitations in the study. For the sampling, the sample size was small, and it was not randomly selected in the Harrison (1988) study. The results can only be generalized to a similar population. However, findings showed that the mean IQ scores of children born preterm were comparable to those of the other studies, and the sample appeared to be representative of the preterm infant population. All the infants' families were in the middle or working class, and they had an average of more than 12 years of education. Parents were relatively well educated, which might limit the generalizabilty of the findings, as this is not typical of the preterm population (Siegel et al., 1982; Watson et al., 1996). However, the environmental effects on the intellectual development of children were not adverse.

For the data collection, there was only one single assessment for the NBAS that might have affected the predictive validity of the measure. Moreover, the rater for the NBAS administration was not blind to the infants' birth status. However, she was well trained, and .90 interrater reliability was achieved during the training. Observations were dictated during the NBAS assessments and reviewed in comparison to the assigned score to ensure that the assessments were reliable. For data analysis, the NBAS test developers have not conducted a normative study, and no cut off point has been established. Different cut off points were tried in the study, and the selected cut off point has limited generalizability due to the small sample size and selected sample. Finally, due to the limitation of research funding, the sample had not been followed and assessed from 3 months until 10 years of age. The degree of variability in intellectual development within the 10 years was unknown.

Recommendations for further research

Findings in the study showed that infants' regulation of state accounted for some of the variance in their IQ's in later childhood. A cause and effect relationship cannot be assumed. It is recommended that the continuity and stability of infants' state ability and their cognitive development should be investigated. Previous studies showed that the NBAS had satisfactory clinical predictive validity when repeated examinations and two raters were used with preterm and full term infants. The study could be replicated with repeated NBAS examinations and the use of two raters. It is expected that the predictive validity of the total NBAS score or the Regulation of state score in detecting healthy preterm infants at-risk for cognitive development would be improved. It is also recommended that a large sample size, high-risk infants, a shorter prediction interval and regular follow up be used in future studies. Normative standardization and the identification of cut off points for the NBAS are needed. Preterm infants' score distribution should be used to derive the cut off points if there is no norms available. Furthermore, perinatal and environmental factors such as children's birth weight, parents' education and family SES may also affect children' s cognitive development. It is suggested that the NBAS examination should be combined with these measures for the identification of at-risk infants. Children with different birth weights and of different social classes should be included so that the perinatal and environmental factors could be examined. Finally, six healthy preterm infants had an FSIQ $\leq$ 85 and did not catch up to the normal full term infants when they were 10 years of age. Although the healthy preterm infants do not have as many risk factors as very low birth weight or extremely low birth weight infants, healthy preterm infants are still at-risk for cognitive delays. There are few studies in this area and further research is needed.

Implications for clinical practice

Although findings in the study showed that the predictive validity of the NBAS for identifying healthy preterm infants in later at-risk for cognitive problem was moderate, there are some implications for clinical practice. First, the Regulation of state score can be an indicator for neurobehavioral disorganization. Brazelton (1990) reviewed the use of the NBAS over the first 15 years, and suggested that infants' coping abilities are stable. Moreover, there is continuity in how an individual handles stress that could be discernible in the newborn period, and Brazelton (1990) recommended that NBAS examiners should focus on the infant's profile of scores as a marker for impairment. The infants' Regulation of state cluster score was related to their later IQ. It is suggested that a low score in the state cluster may indicate the immaturity of the self-regulatory subsystem and neurobehavioral disorganization, that may affect their cognitive development. However, the magnitude of the relationship of the state score and later IQ was low, and thus the state score could not be used alone as a clinical predictor.

Second, some healthy preterm infants may need long term follow up. Findings in the study showed that 29% of the children born preterm did not catch up to the children born full term even when they were 10 years of age. Many occupational therapists may now follow newborns with abnormal neonatal neurobehavioral assessments through infancy (0-12 months), and subsequently discharge them if development appears normal at that time. There may be a need to monitor the development of the infant with low scores in the state cluster. When a child's behavioral state or neuromotor status limit functional performance in cognitive, behavioral or language areas, then the infant or child should be referred for intervention.

Third, for the NBAS administration, although the Regulation of state cluster was a better predictor than the total NBAS score in detecting the cognitive at-risk infants, it is not recommended to only administer the Regulation of state cluster. Brazelton et al. (1987) suggested that infants' use of state and the range of state were the most predictive aspects of the NBAS. It is necessary for the infant to play for a significant period of time in order to produce a complete range of state. Items in the Regulation of state cluster (cuddliness, consolability, self-quieting and hand-to-mouth) were assessed continuously through the NBAS exam which took 20 to 30 minutes. Therapists should administer the whole NBAS exam, and focus on the infant's Regulation of state cluster score if they are interested in later cognitive development.

Finally, the NBAS is a standardized assessment for observing infant's neurobehavior. Therapists should examine the psychometric properties of the assessment, and consider the statistical and methodological concepts in interpreting the test results (Law & Polatajko, 1987). As the NBAS is still being used extensively in the clinical and research area, therapists should regularly review the literature in judging the NBAS 's utility in clinical prediction and be careful in the score interpretation.

Conclusion

The NBAS has been used extensively, studied, modified, praised and criticized in the past two decades. It was the first standardized assessment to measure the neurobehavioral performance in newborns. The exam continues to contribute to both research and the clinical care of young infants. Findings in the study showed that the Regulation of state cluster score was more useful than the total NBAS score in discriminating and identifying infants at-risk in cognitive development, but the NBAS could not be used alone in clinical prediction. However, findings of the study increased occupational therapists and other professionals' awareness of at-risk infants' state regulation ability at an early age, which was explained by the Synactive theory (Als, 1982). Healthy preterm infants in this study had deficits in IQ but in most cases their scores were still in the normal range. Insight into the long-term development of the healthy preterm infants has been gained. Accurate prediction of the healthy preterm infants' at-risk for later cognitive development is complex and difficult. Much of the variance in cognitive development remains unexplained.

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APPENDIX I

Brazelton Neonatal Behavioral Assessment Scale (NBAS)

Item 15. Cuddliness (states 4 and 5)

This is a summary measure of the infant's response to being held in alert states. There are several components which are scored in response to the baby being held in a cuddled position both vertically on the examiner's shoulder, and horizontally against the examiner's chest. The baby's resistance to cuddling should be assessed as well as the ability to relax or mould and cling to the examiner. It is best to give the baby a chance to initiate cuddling. It is only if there in no active participation on the part to the baby or if the baby is unable to relax or mould that the examiner should facilitate cuddling. If the infant does it him or herself, he or she gets a score of 7, 8, and 9.

Scoring

1. Doesn't resist but doesn't participate ether, lies passively in arms and against shoulder (like as sack of meal).
2. Actually resists being held, continuously pushing away, thrashing or stiffening.
3. Resists being held most but not all of the time.
4. Eventually moulds into arms, but after a lot of nesting and cuddling by examiner.
5. Usually molds and relaxes when first held.
6. Always molds and relaxes when first held.
7. Always molds, initially nestles head in crook of elbows and neck of examiner.
8. In addition to molding and relaxing, infant nestles and turns head, leans forward on shoulder, fits feet into cavity of other arm, head nestles in crook of elbow and neck, all of body participates.
9. All of the above, and baby grasps and clings to examiner.