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INTRAVENTRICULAR HEMORRHAGE SEQUELAE IN LOW BIRTHWEIGHT INFANTS: A META-ANALYSIS

by

Shannon G. Thompson

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1993

ACKNOWLEDGMENTS

For my children who gave up so much attention during their very early years, my mother who never doubted my drive and my friends who not only tolerated my obsession but actively supported my efforts, there are not words to express my gratitude.

Shannon G. Thompson

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ABSTRACT

Intraventricular Hemorrhage Sequelae in Low Birthweight Infants: A Meta-analysis

by

Shannon G. Thompson, Doctor of Philosophy

Utah State University, 1993

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Department: Psychology

Technological advances in neonatal care have dramatically improved the survival and disability rates among low birthweight infants (LBW). One common factor associated with later problems among these babies is intraventricular hemorrhage (IVH). A meta-analysis was conducted among LBW infants with and without IVH to determine developmental outcome. More than 450 studies were located. Only 125 studies met inclusion criteria.

Mean effect sizes were computed by comparing the LBW group to either a fullterm control group or to test norms. When compared to fullterm children, LBW children scored worse in all areas except gross motor skills.

Cognitive assessment was done commonly up to 6 years of age. LBW infants scored about 1/2 standard deviation below their comparison group. A positive linear trend was found for severity of IVH: those children without an IVH scored

comparably to fullterm children, while those with severe bleeds were about one standard deviation behind.

Assessment of academic skills was done with the 8- to 11-year olds. There was no information given on presence/severity of IVH. Very few assessments were done. On general academic measures, the LBW children scored about 1/2 standard deviation behind the comparison group.

Over 80% of the language assessments were done at 15- to 38-months of age. LBW children tended to score 1/2 to 3/4 of a standard deviation below the comparison group. The severity of hemorrhage did not mediate these results.

Fine motor assessments were performed on children 9 months to 11 years old. LBW children were about 2/3 of a standard deviation behind the comparison group. These skills were not affected by severity of IVH.

Gross motor abilities were typically measured before the children were 24 months old. LBW children showed more deficits in this area than in any other: almost 90% of a standard deviation behind. Gross motor skills appear to be strongly impacted both by being low birthweight and by the severity of IVH.

Results indicate that IVH is a mediating factor in outcome among LBW infants. More research needs to be conducted on these children when they are school age, so long-term effects of low birthweight can be determined.

(223 pages)

CHAPTER I

INTRODUCTION

Explanation

Technological advances in neonatal intensive care over the past 20 years have dramatically improved the survival and disability rates among the smallest of babies who are born too soon (Ehrenhaft, Wagner, & Herdman, 1989; Orgill, Astbury, Bajuk, & Yu, 1982a; Yu & Hollingsworth, 1980). The morbidity and mortality rates among these infants are dramatically correlated to their birth size.

Low birthweight (LBW) is defined by most practitioners as birthweight less than 2500 grams, while very-low birthweight (VLBW) is less than 1500 grams. The third category, extremely-low birthweight (ELBW) consists of those infants weighing less than 1000 grams. In the United States, approximately 6.8% of all live births are LBW, 1.2% are VLBW or ELBW (Bauchner, Brown, & Peskin, 1988). In the early 1970s, survival rates for the infants in the LBW category were uniformly about 80%, while approximately 50% of the VLBW babies lived past the neonatal period. Yet, as few as 15% of the babies weighing 1000 grams or less were expected to survive (Jones, Cummins, & Davies, 1979). With the technological advances since that time, as many as 70% of these extremely-low birthweight babies survive (Yu, Wong, Bajuk, Orgill, & Astbury, 1986). Table 1 presents published mortality rates for premature infants, based on the year of birth and birthweight.

Table 1

Mortality Rates Among LBW Infants

	Birthweight Category					
	ELBW		VLBW			
Birth Year	Up to 1000	751-1000	1001-1250	1001-1500	1251-1500	Source
	PERCENT OF INFANTS WHO DIED IN THE NEONATAL PERIOD					
1952		96			42	Knobloch et al. (1982)
1961-75	100		83			Jones Cummins, & Davies (1979)
1965-70		86				Alden et al.(1972)
1966-75	91		59			Stewart et al. (1977)
1968-72		71				Grassy et al. (1976)
1973			76			Hack, Fanaroff, & Merkatz (1979)
1973-76			54			Rothberg et al. (1981)
1973-78	90		51	25	12	Saigal et al. (1982)
1974		53				Pape et al. (1978)
1975-77	44					Buchwald, Zorn, & Egan (1984)
1974-80		62			16	Koops et al. (1982)
1976-78	62			18		Ross (1983)
1976-79	77	57				Philip (1981)
1977	47					Saigal et al. (1984)
	75		38			Yu & Hollingworth (1980)
1977-79	30					Buchwald et al. (1984)
1978	54					Saigal et al. (1984)
	37		28			Yu & Hollingsworth (1980)
1979	64					Saigal et al. (1984)
1977-80	79		41			Yu et al. (1986)
		43			15	Yu et al. (1984)
	66					Kitchen & Murton (1985)
1980	52					Saigal et al. (1984)
1980-81	25					Buchwald et al. (1984)
1980-82		77		33	9	Worthington et al. (1983)
1981-83	72		33			Yu et al. (1986)
1984	76		35	13	9	Kraybill, Bose, & D'Ercole (1987)
1985-86	78		54	17	10	Powers & Hegwood (1989)

Since the advent of advanced technologies, more infants are surviving, yet the proportion of survivors with serious handicaps does not appear to have changed significantly (Ehrenhaft et al., 1989; Greenough & Roberton, 1985; Shapiro, McCormick, Starfield, & Crawley, 1983). Thus, this increase in survival rate has resulted in an increase in the overall number of children with long-term disabilities, including cerebral palsy, chronic lung disease, blindness, seizure disorders, pervasive developmental delays, and mental retardation.

VLBW babies are subject to a number of medical complications, many of which are known to increase the risk of developing one or many of these handicapping conditions (Knobloch, Malone, Ellison, Stevens, & Zdeb, 1982; Powers & Hegwood, 1989; Worthington, Lowell, Grausz, & Sobocinski, 1983). The medical complications most noted are respiratory distress syndrome (RDS), pneumothorax, bronchopulmonary dysplasia (BPD), patent ductus arteriosus (PDA), and intraventricular hemorrhage (IVH).

IVH is considered to be one of the most crucial neurological complications all low birthweight infants potentially face, due to its high incidence and potential for damage to the developing neural system (Volpe, 1989a, 1989b). It is characteristic of as many as 35-46% of the babies born before 32 weeks gestation (Ahmann, Lazzara, Dykes, Brann, & Schwartz, 1979; Hawgood, Spong, & Yu, 1984;

Holt & Allen, 1981; Levene, Wigglesworth, & Dubowitz, 1981; Lipscomb et al., 1981; Pape & Wigglesworth, 1979; Papile, Burstein, Burstein, & Koffler, 1978). In one of the more comprehensive studies, a rate of 39% was reported (McMenamin, Shackelford, & Volpe, 1984). By 1987, it was estimated that between 35,000 and 41,000 infants weighing less than 1500 grams were born annually (Volpe, 1987). Assuming the current rate of birth, roughly 13,600 to 16,000 babies experience an intraventricular hemorrhage annually. Given the increasing number of these infants who are surviving, practitioners are faced with a tremendous need to learn of the sequelae to such lesions in order to help design appropriate treatment and educational programming for these children.

Problem Statement

While there is vast literature on how low birthweight infants fare as they age, how these results apply to LBW babies with IVH is quite difficult to interpret for a number of reasons. First, there are simply so many studies, involving different ages and area of outcome, that it is nearly impossible to adequately synthesize the material. While reviews of portions of this literature have been published, none have sufficiently covered the material such that any conclusions can be made for any specific age range or any area of development (language, gross motor, intelligence, etc.).

The second difficulty encountered when attempting to synthesize this research becomes readily apparent after even a superficial examination of the field. Individual researchers typically use different criteria for subject inclusion, such as varying levels of birthweight (i.e., infants weighing less than 1000 grams at birth, those weighing 1001-1500 at birth, etc.), gestational age or presence of specific medical complications following birth. While one research cohort may specifically exclude infants with a certain medical complication, another will not provide any information about the sample characteristics on that variable.

Third, a majority of the studies of low birthweight infants include babies with some grade of IVH, yet do not discriminate between these infants and those without such neurological insult. Typically the outcome data are pooled, making it difficult to determine the effect of IVH on later development. Sadly, such a discrimination would require relatively little effort and yet is seldom done.

Fourth, not only is there a lack of consensus in the subject characteristics, but seldom is there agreement on what measures should be used to assess various aspects of development. Outcome measures vary tremendously, based not only on the area of interest to the researchers, but by type of assessment used. Often this can be predicted by the academic background of the investigators. Medical personnel

are more likely to use clinical assessments (such as the Gesell or the Denver Developmental Screening Test), while psychologists are prone to rely on standardized, psychometrically devised instruments (the Batelle Developmental Inventory, Weschler Preschool and Primary Scale of Intelligence or the Stanford-Binet).

There are numerous areas typically assessed: gross motor, fine motor, language, general development, social, behavioral, and cognitive capabilities, to name a few. The best measure to be used, as well as the area to be assessed, depends largely on the age of the child at assessment and the background, biases, and/or interests of the investigator (medical, psychological, speech/language, physical therapy, etc.). Currently, there have been no comprehensive quantifiable reviews of the literature, particularly one which addresses both the age of the child at assessment and the area of interest.

The problem, then, is that the evidence on the specific effects of IVH in low birthweight infants is difficult to interpret, given the number of studies published and the frequently conflicting results. The purpose of this study, therefore, is to delineate more precisely the long-term developmental sequelae of IVH as an entity separate from low birthweight and the other medical complications often related. The general methodology utilized will be that of a meta-analysis, as described by Glass (1976). In order to

help the reader better understand the variables most relevant to this study, an explanation of intraventricular hemorrhage and known risk factors follows. Chapter III is a critique of those published reviews which purported to synthesize the LBW literature. A description of some of the more common review techniques is detailed in Chapter IV. The methodology used for this study is also described in Chapter IV. Results are presented in Chapter V and the discussion of this study is found in Chapter VI.

CHAPTER II

PATHOGENESIS OF IVH

Site of Hemorrhages

Intraventricular hemorrhage (IVH) is a brain lesion commonly found in infants born prior to 35-weeks gestation. The lesion is usually located in the germinal matrix zone (GMZ), a site most often referred to as the ventricular and subventricular zones in reports of neurodevelopmental brain studies (hence the term "intraventricular hemorrhage") (Volpe, 1987).

Within these subependymal areas (located in the periventricular region over the caudate nucleus) neuronal and glial precursors reproduce and migrate to the various layers of cortex during the third to fifth months of gestation. From the 26th to the 35th week of gestation, the GMZ lines the inside surface of the ventricles and receives a rich supply of arterial blood as it produces neurons and glial cells. This blood supply comes from several major arterial sources, including the anterior cerebral artery, the middle cerebral artery, and the internal carotid artery. This network is continuous if the venous system is well developed.

Three primary vessels converge anteriorly at the foramen of Monro to form the internal cerebral vein, which then switches direction to join the vein of Galen. This U-shape location is a common site for the lesion to occur,

which suggests a developmental type of pathogenic connection. By the 40th week of gestation, the germinal matrix has virtually disappeared.

Etiology

An accepted etiology of IVH is unknown to date. However, several promising hypotheses have been advanced, based on observations of correlates with the lesions.

Neurodevelopmental theory. Several researchers have observed that the GMZ and nearby periventricular white matter are a critical arterial confluence, which is particularly susceptible to ischemic damage. Such injury could predispose the infant to hemorrhaging as well (Hambleton & Wigglesworth, 1976). Pape and Wigglesworth (1979) proposed that this "immature vascular rete" is partially the cause of the hemorrhage, suggesting that the undeveloped, irregular vessels are unable to handle the tremendous blood supply under periods of stress, such as those induced by lack of oxygen or low blood pressure.

Pressure-passive theory. It has been noted that asphyxia and hypotension are common correlates in neonates with IVH. These asphyxiated neonates display impaired autoregulation of cerebral blood-flow, leading to the hypothesis that premature infants are "pressure-passive," meaning they do not have adequate ability to maintain a static blood pressure (Beverly, Chance, Inwood, Schaus, & O'Keefe, 1984; Goldberg, Chung, Goldman, & Bancalari, 1980;

Milligan, 1980). If this is the case, it is suspected that premature infants are unable to regulate cerebral blood pressure following any systemic blood pressure change. Researchers speculate that these infants overreact, either by increasing cerebral blood pressure too much (leading to capillary hemorrhage) or decreasing blood-flow too much (causing ischemic damage) (Beverley, 1987; Miall-Allen, de Vries, Dubowitz, & Whitelaw, 1989; Miall-Allen, de Vries, & Whitelaw, 1987; van Bel, van de Bor, Stijnen, Baan, & Ruys, 1987). Evidence from studies of premature infants' reactions to their new environment further supports this notion of a "pressure-passive" system (Moscoso, Goldberg, Jamieson, & Bancalari, 1983).

This hypothesis has been the focus of numerous physiologic studies, many involving animals. Newborn beagle puppies have been found to have intraventricular hemorrhages that are pathologically very similar to those seen in human infants. Goddard-Feingold and her associates (Goddard, Lewis, Alcala, & Zeller, 1980; Goddard, Lewis, Armstrong, & Zeller, 1980; Goddard-Feingold, 1984; Goddard-Feingold & Michael, 1984; Goddard-Finegold & Mizrahi, 1987) have studied the relationship between blood pressure changes and IVH. They found that rapid re-expansion of blood fluid volume (such as that following blood infusions or sodium bicarbonate infusion) resulted in an increase in cerebral blood-flow, causing hemorrhages in a significant number of

puppies. They hypothesized that the rapid shift in cerebral fluid volume caused a diversion of blood-flow to the GMZ, which, once started, could not be readily reversed (Goddard-Feingold & Mizrahi, 1987).

Hemostatic disorders. Coagulation defects have been implicated in the etiology of IVH, either by initiating the bleed or prolonging it. Early on, autopsy studies found that those infants with IVH were found to have deficiencies in coagulation and platelet aggregation (Foley & McNichol, 1977; Gray, Ackerman, & Fraser, 1968). With the advent of ultrasound, diagnosis of IVH is much more accurate and can be correlated to the immediate hemostatic response. Hypocoagulability has been found in infants with IVH, as evidenced by lower platelet count, lower concentrations of clotting factors, diminished mean platelet aggregation response, longer mean prothrombin time, and longer mean activated partial thromboplastin time than infants without IVH (McDonald et al., 1984; Setzer et al., 1983; Setzer et al., 1982).

Risk Factors Correlated with IVH

Obstetric variables. Premature infants born under certain circumstances have been observed to be more or less likely to develop IVH. For example, maternal toxemia is known to decrease the chance that the preterm infant will develop IVH, respiratory distress syndrome (RDS), or retrolental fibroplasia (Leviton et al., 1988). When the

mother experienced significant bleeding following delivery, the infant was found to be at increased risk for IVH (Clark et al., 1981).

Other obstetric factors seem to be related to the development of IVH. One question that has been repeatedly considered is the effect of route of delivery. Many researchers suggested it might be safer to deliver preterm infants via cesarean section rather than vaginally so as to decrease the risk of IVH (Horbar, Pasnick, McAuliffe, & Lucey, 1983; McDonald et al., 1984), based upon a correlation between this route of delivery and lower rates of IVH. Given that elevations in neonatal systemic blood pressure have been noted following vaginal delivery (Adams, Pasternak, Kupfer, & Gardner, 1983; Moscoso et al., 1983), this is a reasonable conclusion, since one proposed method of reducing the risk of IVH is to maintain blood pressure stability. Upon further investigation, this relationship became less clear (Elghammer, 1988; Leviton, Pagano, & Kuban, 1988; Meidell, Marinelli, & Pettett, 1985; Rayburn, Donn, Kolin, & Schork, 1983) and has yet to be resolved.

Several different cohorts have suggested that the presence, length and/or duration of labor may also increase the risk of IVH (Horbar et al., 1983; McDonald et al., 1984; Meidell et al., 1985; Tejani et al., 1984). Upon further investigation, it seems there is a relationship between presence of labor and risk of IVH, but it interacts with

other factors, such as presentation of the infant, route of delivery, and if the infant is a singleton. For example, it has been noted (Morales & Koerten, 1986; Tejani, Verma, Hameed, & Chayen, 1987; Tejani, Verma, Shiffman, & Chayen, 1987) that cesarean sections are associated with a decreased risk of IVH only for infants in the breech presentation. van de Bor, van Bel, Lineman, and Ruys (1986) also found this relationship, but observed that infants in the breech presentation tended to be of younger gestational age and more prone to IVH than those with a vertex presentation. It is likely that this correlation is tempered by other factors, since not all researchers have found the same relationship (Clark et al., 1981).

Welch and Bottoms (1986) investigated the relationship between a number of obstetric variables, such as when membranes ruptured in the process of labor, mean duration of labor, presence of abnormal labor signs, method of delivery, delayed amniotomy (breaking the membranes well into labor rather than after dilation of 3-5 centimeters), use of episiotomy to prevent pressure on the skull, and the use of forceps. They found no significant differences between those infants who later developed IVH versus those who did not. This study utilized a retrospective sampling procedure, with all subjects being scanned by ultrasound at 72 hours for the presence of an IVH. They concluded that fetal head compression from vaginal delivery is not a

concomitant of IVH.

In addition to the obstetric variables mentioned above, they also measured maternal characteristics in an effort to relate these to the probabilities of an infant experiencing an IVH. When assessing demographic information such as age, race, parity, and number of living children, they found there was not a statistical difference on any of these factors between those infants with brain hemorrhages and those without.

Fetal and immediate neonatal characteristics. In an effort to identify the infants most at risk for IVH as early as possible, several research cohorts have attempted to find fetal or immediate neonatal variables which correlate with a higher or lower rate of IVH. For example, it is known that infants born outside of the prenatal intensive care centers and then transported to the centers are at increased risk of IVH, as well as a number of other medical complications. This is most likely related to the rational for transporting infants (the infant must be fairly sick for him/her to need the intensive care unit) rather than a difference between those infants born in the centers versus those outborn. Those infants inborn were also more likely to receive the immediate medical attention necessary for them to become more stabilized (Clark et al., 1981).

A relationship has been noted between the amount of birth trauma, and consequent cranial bruising, the infant

experienced and an increased probability that s/he will also develop an IVH (Szymonowicz, Yu, & Wilson, 1984). Acs and Kilchevsky (1986) have suggested that cranial bruising may actually be the confounding factor in other studies of associated obstetric conditions and treatments which resulted in the confusing outcomes.

Those infants who were administered antenatal steroids prior to delivery were found to be significantly less likely to develop IVH (Clark et al., 1981). It is likely this relationship is secondary to the fact that these infants had lower rates of RDS, which helped maintain more constant blood pressure and required fewer nursing interventions.

Fetal heart rate tracings have also been related to the risk of IVH. Those infants with "reassuring" heart activity (normal or mild to moderate variable decelerations) were found to have significantly fewer bleeds than did those with "suspicious" (intermittent late decelerations, decreased heart rate variability, or tachycardia) or "ominous" (severe variable decelerations, persistent, or prolonged late decelerations) readings (Strauss, Kirz, Modanlou, & Freeman, 1985).

Perinatal interventions known to increase blood pressure. Based on the pressure-passive theory of etiology, it is presumed that any intervention or complication which increases blood pressure would predispose the infant to suffering an IVH. Elevations in arterial blood pressure

have been documented to occur following nursing interventions (Bada et al., 1990a; Bada et al., 1990b; Kling, 1989; Lou, Lassen, & Friis-Hansen, 1979), tracheal suctioning (Perlman & Volpe, 1983), and administration of mydriatics (Isenberg & Everett, 1984; Lees & Cabal, 1981).

Perinatal complications known to increase blood pressure. Blood pressure elevations have also been noted to occur with treatments for systemic complications such as RDS (Bada et al., 1990b; Kendig & Sinkin, 1988; Perlman, McMenamin, & Volpe, 1983; Welch & Bottoms, 1986) pneumothorax (Goldberg, 1981; Greenough, Morley, & Gandy, 1983; Hill & Volpe, 1981; Hillman, 1987; Lipscomb et al., 1981; Thorburn, Lipscomb, Stewart, Reynolds, & Hope, 1982) hypovolemia (Goldberg et al., 1980; Milligan, 1980) hypotension treatment and blood pressure changes (McDonald et al., 1984) and patent ductus arteriosus (PDA) (Bejar et al., 1981a; Bejar et al., 1981b; van de Bor et al., 1986; Marshall, Marshall, & Reddy, 1982). It is also suspected that each of these complications may increase the risk of IVH.

Perinatal variables otherwise correlated with IVH. There are a number of factors associated with IVH which did not necessarily increase systemic blood pressure. It has been observed that those infants with intraventricular hemorrhage were significantly more likely to have experienced lower 1-minute and 5-minute Apgar scores

(considered a measure of fetal depression and/or asphyxia) (van de Bor et al., 1986; McDonald et al., 1984; Strauss et al., 1985; Welch & Bottoms, 1986) and lower birthweight (van de Bor et al., 1986). There also seems to be a significant correlation between lower birthweight and depressed 1-minute Apgar scores.

Immaturity has also been identified as one of the primary factors correlated with IVH (van de Bor et al., 1986; Guggenheim et al., 1980). In one sample (Guggenheim et al., 1980), infants born prior to 32-weeks gestational age had a uniform rate of 67% experiencing IVH. Those born after 32 weeks "rarely" had IVH. In addition to immaturity, this cohort also noted higher rates of IVH among those infants requiring assisted ventilation. While Guggenheim reported that males had slightly higher rates of IVH, this relationship has not been found consistently (van de Bor et al., 1986; Strauss et al., 1985). Infants who had blood transfusions within 24 hours of birth (following hyperbilirubinemia) have also been found to be at increased risk (van de Bor et al., 1986; Guggenheim et al., 1980).

Summary

From the evidence discussed above, the following conclusions can be made. The infant most susceptible to periventricular-intraventricular hemorrhage is the low birthweight neonate born prior to 32-weeks gestation, with respiratory distress, requiring mechanical ventilation. The

infant is also likely to have experienced intensive nursing interventions as a result of other complications of immaturity such as acidosis, pneumothorax, retinopathy, hyperbilirubinemia (resulting in the need for blood transfusions), and patent ductus arteriosus.

CHAPTER III

OUTCOME REVIEW STUDIES

Due to the potential severity of an intraventricular hemorrhage, the high rate at which it occurs among premature infants, and the increased numbers of neonates surviving with this complication, it has become very important to determine the sequelae and long-term prognosis of those infants who have experienced an intraventricular hemorrhage. Numerous researchers have investigated different aspects of this population.

There are two main lines of outcome research relevant to this project: studies of low birthweight children in general, and studies of low birthweight children with IVH. Within these two areas there are several typical outcomes measured: growth rate, neurological status, presence of major disabilities, rate of motor development, intellectual capabilities, language development, and social skills are a few. The age at which the children are assessed is yet another major factor to be considered when reviewing the literature. When this literature was reviewed, well over 450 outcome articles were located. Yet a thorough search of the literature to date yielded only a handful of review articles synthesizing the vast body of research.

One of the reviews identified, that by Ozminkowski, Wortman, and Roloff (1988), used a meta-analysis to evaluate the effect of inborn/outborn status on the rate of survival.

Since they did not pursue outcome past the neonatal period, their data are not relevant in determining long-term outcome.

Review by Scott

One review, published by Scott (1987), began by reiterating the pioneering work of C. M. Drillen. Dr. Drillen followed premature children born in Edinburgh between the years of 1948 to 1960 and 1966 to 1971. The children in the earlier sample were followed up to 5 years of age, while the later born children were followed continuously to age 1 year and then assessed at 6 to 7 years of age. Drillen assessed the first cohort by birthweight and social class. The outcome was discouraging: over one-third were not able to attend regular schools due to physical or cognitive limitations, another third were classified as retarded, but attended the regular school, and less than a third were performing at grade level.

The second group of LBW infants, those born between 1966 and 1971, were grouped by birthweight (1500 grams or less, 1501 to 1750 grams, and 1751 to 2000 grams), weight for gestational age (those below the tenth percentile and those who were above the tenth percentile), and social class. In order to further classify the infants, Drillen attempted to determine the cause of prematurity: developmental fetal abnormalities, severe pregnancy related complications, and normal infants born early for some

unknown reason.

The first year follow-up of these children revealed the well-documented inverse relationship between birthweight and number of abnormalities. The small-for-gestational-age infants also showed significantly more developmental delays. The etiological categorization proved most useful in predicting outcome and Drillen indicated she thought the fetal abnormality group beyond the reach of medical intervention.

Testing of these children when they entered school indicated the significant impact of social class. She reported an inverse linear relationship between IQ scores on the WISC and social class. Again, the most striking relationship was between purported etiology of the prematurity and school-age outcome, with those children in the fetal abnormality group showing the most delay. While Drillen attempted to assess the importance of various neonatal complications, she found an important confound: most of the infants with the fetal abnormalities experienced more complications and did so more severely than the other two groups of infants. Scott summarized by quoting Drillen's conclusions:

> Thus, one may say that with improved perinatal techniques the survival rate has improved and the incidence of handicap among survivors has not increased. Cerebral palsy has decreased in LBW survivors (Hagberg, Hagberg, & Olow, 1975), but, as far as it is possible to assess by going back over old data, the decrease in this type of handicap may be matched by an increase in survival of infants who have

> suffered early intrauterine insult. The majority of low birthweight infants can now be expected to enter normal primary school: 92% of surviving children who were traced in the Edinburgh follow-up study were attending normal school at age 6 years, 8 months. Those who showed no evidence of early intrauterine insult and who were neurologically normal in the first year of life were largely indistinguishable from control children reared in similar homes. (p. 193)

Scott then reviewed the Comprehensive Development Screening Program which assessed all children born in Dundee, Scotland, from 1974 to 1975. It cannot be determined from the review the age at which the children were assessed, or on what measures. The sample consisted of all children who were developmentally delayed, whether full term or preterm. Thus, the results are not strictly applicable to this review. However, significant relationships were again found between the likelihood of developmental delay and social class (inverse), obstetric complications (positive) and neonatal complications (positive).

Following this, Scott chose nine studies published between 1982 and 1987 which he summarized in a narrative format. He gave no rationale for why he chose to review these particular studies, which is confusing since there were literally dozens of outcome studies published in the years 1982 to 1987. Four of the nine studies had such significant subject mortality (ranging from 32 to 85% of the initial sample) that the results are of questionable validity. Another study assessed performance on the

Stanford-Binet at age 5 years. While 38% of that sample came from homes in which English was not the primary language, all subjects were assessed on an English version of the test. Not surprisingly, social factors, such as indicators of socioeconomic status, were more important than any other variables in predicting outcome. It is difficult to determine the usefulness of this study in assessing LBW outcome.

The sixth study reviewed by Scott excluded all "abnormal" preterm infants from their sample and concluded these children did just as well on cognitive assessments as their 5-year-old peers. However, there were data to suggest delays even among this group in the areas of visual motor functioning and eye-hand coordination.

Another study reviewed by Scott attempted to predict IQ for the population as a whole at age 7 through various factors. While socioeconomic status may be the most important factor for fullterm infants, such an assumption cannot be made about preterm infants, because of the unknown impact of the numerous medical complications they tend to experience.

The final study followed 33 infants up to the ages of 5 to 8 years. They concluded that the children did as well as their siblings on cognitive measures and they were not overrepresented in special education classes. However, this is a troublesome conclusion to draw from such a small sample

of children who were assessed prior to the age most children are diagnosed with learning disabilities and/or behavioral problems.

Scott (1987) summarized his review by reiterating that which is well known to most social scientists:

> ...in a human population at least, biological factors seldom operate in a socioeconomic vacuum. More than anything else, it is probably this covariation of risk factors from multiple domains (genetic, nutritional, educational, obstetric, neonatal, environmental) that accounts for the heterogeneity in the etiological factors that are usually cited as causes for childhood neurodevelopmental handicapping conditions. (p. 198).

While this is undoubtedly true, these individual factors also have a unique contribution to the outcome of LBW infants and it is this contribution which is yet to be determined.

Review by Page

Page's (1986) purpose in reviewing this literature was to delineate those variables most relevant in predicting LBW infants' outcome. As with Scott's review, Page did not provide reasons for how the articles were chosen or even the specific variables which were evaluated. Also, the review was done in narrative form, drawing conclusions from typically one or two studies. This type of review is particularly subject to bias, unless there is strong, absolutely consistent research support for the conclusions being drawn.

In reviewing the relationship between obstetric,

intrapartum, and neonatal risk factors, Page concluded that no "single variable was found to be a reliable predictor of later abnormality" (p. 1252), nor were groupings of these variables any better at prediction. Page then evaluated studies which looked at the correlation between abnormal neurologic findings in the neonatal period and later handicaps. Page concluded that most infants who had abnormal exams were "normal" later, although a couple of the cited researchers expressed concern these children may display learning and behavior problems in school. Sociological factors were determined to be the most important group of variables in predicting long-term outcome of these infants. Infant optimality indexes, which incorporate antenatal, intrapartum, neonatal, and socioeconomic factors, were found to be "highly accurate" (p. 1253) in predicting outcome among fullterm infants, but, according to Page, had far too many false positives among LBW infants.

Overall, Page's commentary is typical of a narrative approach and certainly has the limitations of most narrative reviews. She cites approximately 30 articles, which she presumes adequately cover the research on the impact of antenatal, intrapartum, perinatal, and sociological factors as they related to LBW infant outcome. She does not specify the type of outcome measured, nor the age at which the children were assessed. Conclusions were drawn with no

evidence for the reader to assess for him/herself. Her conclusions are vague, similar to those presented by Scott and provide little information beyond recommendations for future research.

Review by Stewart, Reynolds, and Lipscomb

The review by this group (1983) was a much more systematic effort in determining how low birthweight infants fared depending on the year they were born. Their major thesis is that LBW infants born prior to 1960 had significantly higher mortality rates than those born after. Given this, there have been many practitioners concerned that children are surviving with a higher incidence of handicapping conditions. This review attempted to answer this concern.

The cohorts "reviewed the literature" but did not report specifically how extensively they searched for relevant publications. Studies had to present "reasonably satisfactory information," which consisted of the following inclusion criteria: "Results were included only if all live births in the population studied were accounted for, in terms of total mortality, children lost to follow-up, and the prevalence of defined handicaps in survivors at a minimum age of 12 months" (p. 1038). Handicapping conditions were defined as those which would presumably have

an effect on the child's ability to lead a normal life or obtain employment as an adult, such as IQ/DQ two standard deviations below the mean, cerebral palsy, hearing or vision loss which required special schooling, and hydrocephalus. Minor handicaps were not considered in their outcome analysis.

Twenty-two studies met the inclusion criteria, which included infants born as far back as 1946. Several well-known reports were excluded because they did not provide adequate information regarding mortality. The infants were placed in the categories of dead, handicapped, lost to follow-up, or healthy.

The data indicated that from 1946 to 1960, more infants were surviving but with more handicapping conditions. From 1960 through 1977 the proportion of infants surviving almost tripled, while the rate of handicaps remained relatively stable (6 to 8%). From 1946 on, the proportion of infants surviving with no major handicap has significantly increased.

While this review succinctly enunciated trends in infants mortality, there are gaps in the morbidity results. Of primary concern is the categorization of handicapping conditions. Each of the 22 articles used in this review presented data within the categories of normal, suspect, and/or abnormal. Stewart and her cohorts obviously had to make individual decisions regarding how to classify these

categories into either normal or handicapped, but did not provide information on their decision-making process. It is also troublesome that only major handicaps were considered in the morbidity estimates. Certainly this is an underestimate of the actual morbidity rates when other sequelae (mild mental retardation, learning disabilities, permanent respiratory difficulties, etc.) are included. Furthermore, the "outcome" studies need only have followed the infants to 12 months of age. It is well documented that early estimates of cognitive, language, and learning abilities are frequently inaccurate.

It is very difficult to determine how these results apply to LBW infants with IVH, since there was no mention of any medical conditions which affected outcome. Additionally, it was difficult to diagnose IVH prior to the routine use of CT scans, which were not readily available when the majority of these infants were born. Therefore, there is no way to assess the long-term impact of IVH as separate from being born too soon.

Meta-analysis by Aylward, Pfieffer, Wright, and Verhulst

The review by Aylward, Pfieffer, Wright, and Verhulst (1989) is a considerable step forward when compared with those reviews mentioned above. This research team utilized a meta-analytic method to examine studies on the sequelae of

low birthweight infants. First, the authors stated very clearly they were interested in those articles which addressed the outcome of infants that weighed less than 2500 grams at birth. It appeared that the authors attempted to locate all studies published in approximately 1978 and 1979, although exact dates were not included in the article.

A total of 80 empirical studies met their inclusion criteria. Data were obtained in three broad areas: subject characteristics, methodology, and environmental factors. Subjects were grouped by gestational age and birthweight. Birthweight was grouped into three divisions: 1) low birthweight [1501 to 2500 grams], 2) very-low birthweight [1001 to 1500 grams], and 3) extremely-low birthweight [less than 1000 grams]. Methodology variables considered were: experimenter blindness, type of comparison group used, type of statistical analysis employed, if a correction for prematurity was used, and type of experimental design (prospective or retrospective). Environmental factors consisted of mother's educational level and SES level.

Outcome variables incorporated age of the infant at assessment, specific outcome measure(s) employed, and diagnostic criteria used to categorize the sequelae. Over 4,000 children were categorized as either low birthweight, very-low birthweight, or extremely-low birthweight. An additional 1,568 control subjects were culled from the 80 studies.

Intelligence and developmental tests were among the primary assessments used. The average IQ/DQ (developmental quotient) score for the low birthweight infants as a group was found to be 6 points less than the controls. Although this is a statistically significant difference, it is within the standard error of measurement for the tests used and was determined to be of little clinical significance. No difference was found in IQ/DQ scores among the three birthweight groups.

Several recommendations were made for future research. Aylward et al. (1989) suggested that researchers control for type of low birthweight, that is, premature infants with average gestational size, premature babies with small-for-gestational-size weights, and term infants classified as small-for-gestational-age. Because background and environmental factors have been found to be strongly associated with outcomes for premature infants (Aylward et al., 1989), it was suggested that future studies be designed to control for this factor.

While Aylward's meta-analysis was a significant effort in synthesizing the diverse research in the area, it left several questions unanswered. As mentioned earlier, the prognosis for premature infants has changed substantially over the past 20 years. Aylward et al. (1989) included infants born as early as 1960, without controlling for the differential rate of survival and handicapping conditions at

the time of the infant's birth. Also, the authors indicated awareness that environmental factors have an impact on how premature infants fare, yet they did not provide results of any analyses which controlled for these variables. Further, they asserted medical complications are important in the outcome of these children, but provided no measure to assess this. The absence of a control for brain hemorrhages is also a glaring weakness in the design of this study.

Several authors have indicated that premature infants, particularly those with brain hemorrhages, are at risk for subtle dysfunctions in learning, behavior, and motor capabilities (Eilers, Desai, Wilson, & Cunningham, 1986; Klein, Hack, Gallagher, & Fanaroff, 1985; Nickel, Bennett, & Lamson, 1983; Vohr & Garcia-Coll, 1985). Many of the studies included in Aylward's analysis provided some type of data concerning the presence of these subtle disabilities, yet these results were not included as variables in this meta-analysis. Furthermore, the classification of children as normal, suspect, or abnormal only serves to obscure the relationship between these disabilities and complications of premature birth. Details about the specific deficits, their prevalence, and nature would be more useful information.

Aylward's review indicates the need for a more comprehensive and systematic review of the literature on the outcome of low birthweight children. This meta-analysis is proposed in order to address these deficits.

CHAPTER IV

METHOD

Review Procedures

In this section the methods typically used to review existing research are described and evaluated. A description of the method chosen for the proposed research will also be included as will the reasoning for choosing this approach over the others.

The literature identifies at least five types of review procedures used to integrate research findings in a cohesive report. First, the narrative review is most commonly used by researchers. Second is the vote-count method, which has been advocated when checking for strongly consistent findings in a relatively quick fashion (Carlberg & Walberg, 1984). The third method, combining probabilities, is an integrative method suggested by Rosenthal (1978) to increase the power of statistical analyses by massing sample size to obtain lower probabilities. Glass (1976) proposed the fourth method, called the meta-analytic approach, so as to utilize both quantitative and qualitative information in a more scientifically rigorous manner than the other methods mentioned so far. Finally, Slavin (1986, 1987) attempted to combine the best features of meta-analysis with the narrative report in what he termed the "best evidence approach." Although meta-analysis procedures will be used in the proposed study, the five review methods will be

discussed briefly, so as to better explain the choice of the meta-analytic procedure.

Narrative review. The narrative review is the traditional method of synthesizing numerous studies in a descriptive summary. According to Light and Smith (1971), such reviews typically involve the following steps: (a) a set of studies on a particular subject is collected; (b) the studies are read and inspected, eliminating those which contain serious weaknesses; (c) the remainder are described according to method of study and results; (d) conclusions are drawn based on consistencies in outcomes. This method has been strongly criticized because it is subjective, is scientifically unsound, and is an inefficient method for extracting useful information from a large body of literature (Cooper, 1983; Jackson, 1980; Light & Pillemer, 1982).

Vote-count method. With the vote-count method the researcher uses the tests of statistical significance from the individual studies reviewed. Results are tallied into categories such as significantly positive, nonsignificant, and significantly negative. The category which contains the majority of "votes" is concluded to be representative of the reviewed body of literature (Carlberg & Walberg, 1984; Light & Pillemer, 1984). The simplicity of this method leads to its numerous drawbacks. Because interval level data are placed in discrete categories, much information is lost.

The ability to discriminate between different treatments or to assess relative treatment results is lost with this technique (Glass, 1976). Furthermore, relevant study characteristics and results such as sample size, interaction effects, and quality of research design are ignored (Hedges & Olkin, 1980; Kavale & Glass, 1981; Paul & Licht, 1978). Most reviewers who utilize this method do not provide descriptive information about the studies, though this technique does not preclude one from doing so (Glass, McGaw, & Smith, 1981).

Combined probabilities method. In an attempt to correct some of the above difficulties, Rosenthal (1978) proposed the combining probabilities method. Rather than simply lumping results into broad categories, Rosenthal suggested that the results of individual significance tests be added, allowing for greater statistical power, particularly when the results are based on small samples. The problems with this method are similar to those of the vote-counting technique: different research designs are not considered separately, design confounds and sampling problems are pooled together, and interaction effects are ignored (Cook & Leviton, 1980). Also, similar to the vote-counting method, most researchers who employ this procedure fail to provide detailed information from the individual studies cited, though again, there is no constraint in this regard.

Meta-analysis. Glass (1976) attempted to address these difficulties by proposing the meta-analysis approach, a comprehensive quantitative review of the research on a specific topic. According to Glass, a meta-analysis differs from the previously discussed types of reviews in that (a) the sample or population of studies to be reviewed is explicitly defined, including exclusionary criteria; (b) the outcomes from all studies are quantified using a common metric; (c) outcomes are examined for covariance with individual study characteristics; and (d) the procedures for data collection and rationale for conclusions are explicit and replicable.

This technique has numerous advantages, summed up by Kavale (1984):

> 1. Quantitative methods [are used] for organizing and extracting information from a large data base.
> 2. Bias in study selection [is reduced] by not prejudging research quality.
> 3. Information [is made use of] by transforming study findings into commensurable expressions describing the magnitude of the experimental effect.
> 4. Interactions [are detected] by studying the covariation between findings and study features that are quantitatively defined and measured.
> 5. General conclusions aimed at practical simplicity that do not do violence to more interactive conclusions [are sought]. (p. 62)

Schmidt (1992), in a review of the meta-analytic approach to research, indicated that "the significance test actually obscures underlying regularities and processes in individual studies and in research literatures" (p. 1173). He found that "these procedures, based on statistical

significance test and the null hypothesis, logically lead to erroneous conclusions because they overestimate the amount of information contained in individual studies and ignore Type II errors and statistical power" (p. 1180). He went so far as to suggest that routine use of meta-analysis on large research bodies could potentially change the process of scientific discovery.

These strengths notwithstanding, meta-analysis has been sharply criticized by several researchers. The most prominent criticism has to do with allowing poor quality studies to be included in the review. In what is akin to a "smoke screen" (Wilson & Rachman, 1983) poor quality studies are obscured by the use of objective procedures and statistical techniques. Slavin (1984) asserted that poor quality studies may be biased in some systematic fashion, allowing for a specific confound to be introduced. Eysenck (1984) was so blunt as to say, "Garbage in, garbage out" (p. 44).

Glass (1982) had already dealt with this potential difficulty when he advised that study quality should be one (or more) of the variables coded from each study reviewed. In this way, if outcomes covary with quality, low quality studies can be excluded from future analyses. Bangert-Drowns (1986) proposed that when a priori reasons exist for concerns about specific types of poor quality designs, exclusionary criteria can be defined and such studies

excluded from the subject pool.

One major source of criticism of meta-analysis has to do with the violation of the assumption of independence of the data. Glass et al. (1981) found that such violations tended to lead to reduced reliability of estimations of regression equations and grouped effect sizes. Glass et al. (1981) recommended two solutions to this problem: (a) use only those results which are completely independent, or (b) employ Tukey's jackknife regression analysis. Landman and Dawes (1982) applied Tukey's jackknife procedure to Smith and Glass' (1977) psychotherapy meta-analysis and concluded that the results obtained thus were not appreciably different from the original report.

Best-evidence approach. Contrary to Glassian meta-analysis, Slavin (1986, 1987) proposed to overcome the difficulty of poor quality study inclusion through the "best-evidence approach." He recommended that only the studies of highest quality and relevant to the objective of the paper be reviewed. In addition to the steps taken to conduct a meta-analysis, Slavin advocated that following the quantitative results, a thorough narrative of the conceptual findings be reported. Thus, Slavin urged the use of the best features of the two most commonly used methods.

While Slavin's comments make intuitive sense, Joyce (1987) noted that these are unnecessary restrictions, allowing for subjective bias to enter into the sampling

process. Further, Slavin has really only recommended a variation on the basic meta-analytic procedure. According to Joyce (1987), when conducted properly, a meta-analysis should include controls for the quality of the studies and how that might be related to obtained effect sizes.

The five methods of critique outlined here are the major approaches typically taken by reviewers. Although each has strengths, a combination of the meta-analytic technique and the best evidence approach seems to meet the needs of this literature assessment by providing for a quantitative review of many studies, while controlling for the quality of the research.

The meta-analytic model allows for the comparison of outcomes from different dependent variables (such as various intellectual/developmental tests) through a common metric, the mean effect size. Researchers can then systematically examine how individual study influence results. Should results come under close scrutiny, sufficient documentation can be provided for complete replication. In addition, it is possible to select inclusion criteria appropriate to the research question and make whatever narrative comments seem necessary to completely convey the nature, outcomes, and the interpretations of studies under review. For these reasons, it was determined that this method best fit the needs of this particular research question.

Selection of Studies to be Included

Goal statement. The purpose of this meta-analysis is to determine how children fare when they have experienced periventricular-intraventricular hemorrhage (PV/IVH) as a low birthweight infant, as a factor separate from being born too early and/or too small, as well as the medical complications frequently experienced. The information used to learn of this effect is the body of literature found in publications and that presented at conferences.

Therefore, attempts were made to find as many published studies as possible which followed children who were low birthweight, particularly those published since 1980. Many studies of low birthweight infants in general include those with PV/IVH in their sample, with the results for both groups presented, sometimes separate and sometimes combined. In order to compare the hypothetical differences between those preterm infants with and without PV/IVH, as well as control for the numerous medical complications, studies which address the outcome of the low birthweight infants without IVH were included in the sample.

Location procedures. Due to the importance of obtaining an unbiased, comprehensive sample, several steps were taken to find as many published reports dealing with outcomes of low birthweight infants as possible. Four major steps were taken to do this.

1. A computer-assisted search was undertaken.

Psychological Abstracts, Medline, Dissertation Abstracts International (DAI), and Education Resources Information Center (ERIC) were all searched.

2. Relevant reports from this search were obtained.

3. Government documents, federally funded projects, and Thesis Abstracts International were searched. Convention programs from relevant disciplines such as the American Psychological Association, the American Medical Association, special education, and nursing were also checked.

4. After obtaining reports from the above sources, reference lists from more than 75% were searched. After 75% had been searched, there were virtually no new articles found and the search was considered finished. This was an important step in getting a comprehensive sample, since the initial computer searches only provided about 40% of the actual titles.

Inclusion criteria. Reports included in this study were those written in English (due to translation limitations) that addressed the outcomes of low birthweight infants (less than 2500 grams), with and without intraventricular hemorrhage. Following an extensive search of the literature (as detailed above), over 450 studies were located (See Appendix A). In an effort to eliminate some of the confounds of previous research, the following exclusion criteria were developed:

1. Studies which include infants weighing more than

3000 grams at birth were excluded, since this is considered the absolute upper limit for low birthweight status.

2. Studies which incorporate a form of treatment or intervention were included only if baseline or control group data (for low birthweight infants) were provided. Data obtained following any intervention or treatment other than that deemed medically necessary for the infant's survival were excluded.

3. Those reports which include fullterm, small-for-gestational-age (SGA) children were not included unless the data was presented separately. Because these premature infants are subject to the additional difficulties of intrauterine growth retardation (Desai & Cunningham, 1986), the general consensus is that they are not from the same category of prematurity as average-for-gestational-age (AGA) premature infants. The SGA infant is known to experience greater mortality and morbidity than AGA preterms (Francis-Williams & Davies, 1974; Koops, 1984; Vohr & Oh, 1983; Vohr, Oh, Rosenfield, & Cowett, 1979).

4. Those studies which provided "outcome" data on only the neonatal period (28 days following birth) were not included in the analysis, since the primary focus of this period is survival through medical intervention. Few of these studies assessed neurological or developmental status of the infant. When done, such measures are, by necessity, extremely crude, with relatively poor reliability in

accurately predicting outcome at a later age.

5. Related to the above criteria, those studies which gave only growth data were excluded from the sample, since this is not a variable of interest, nor is it strongly correlated with psychological outcome measures such as intelligence, motor abilities, temperament, or behavior.

6. Those studies which detailed outcome in categories of "normal," "suspect," or "abnormal" had to be excluded. There were three major reasons for this. First, each research team used different diagnostic criteria in their classification system. While there is relative agreement as to what constitutes definite impairment or disability, the categories of suspect/borderline and normal are fraught with debate. This is particularly true for neurological assessments, which are primarily based on clinical judgment. If analyses were performed on these data, it could not be generalized to the population as a whole, given the lack of agreement over what constitutes normalcy or otherwise. Second, such classifications are not objective, nor are they quantifiable. They provide little information on the subtle difficulties these children may experience. Third, it is difficult, if not impossible, to derive an accurate effect size for such categories, when population norms are unavailable and control groups were seldom used.

After reviewing all the articles, 125 studies were found to meet the inclusion criteria. The citations for

articles which constitute the data base for this study can be found in Appendix B. Those articles located which did not meet inclusion criteria are cited in Appendix C.

Data Collection

Data were collected from the individual studies by coding relevant information in a quantified form. Following several revisions, a coding sheet was developed and tested on approximately 10% of the studies to be used in the analysis. Following this pilot testing, the coding instrument was again revised to better reflect trends in reporting of data. The final coding form and dictionary can be found in Appendix D.

The areas assessed at various ages were typically measures of developmental status, temperament within the first months of life, developmental quotients, motor and language capabilities as toddlers, as well as cognitive and learning capacities in the school years.

Use of Effect Sizes As Data Points

The dependent measure used in this meta-analysis is a standardized mean difference effect size. Outcome data from each study were converted to effect sizes by standardized equations. It was necessary to use different equations to compute the standard mean difference effect size depending on the type of data provided. For specific formulas used, see Appendix E. Test norm information is also provided in

that appendix. These were used when the LBW group was compared to the test norms rather than a fullterm control group.

CHAPTER V

RESULTS

Data Characteristics

Description of data. From the years 1976 to 1991, 125 studies were found which met the inclusion criteria. Within these 125 studies, 225 separate groups of infants/children were low birthweight and assessed at least once following the neonatal period. Of these 225 groups of children, 84 were assessed at more than one age on any given measure, providing a total of 309 separate comparisons between LBW infants/children and fullterm controls or to population norms at that particular age. These comparisons of LBW children constitute the "subjects" of this research. Hence, unless otherwise noted, in the tables that follow the "N" refers to the number of groups which provided data for the comparison of LBW infants/children to either fullterm controls or to population norms at that particular age of assessment.

Despite the fact that there were 309 separate comparisons, these came from only 225 groups studied by the various research cohorts. If background characteristics were presented on each of the 309 comparisons, those studies which provided information on more than one comparison would unfairly bias the information on the study characteristics, such as type of research design, quality of study, and so on. Therefore, in the following tables, the "N" is the number of separate groups of children used in the research,

regardless of how may different times they were assessed or at which ages.

Over half of the 225 groups were from the United States and another nearly 20% were born in Australia or New Zealand (Table 2). Most of the information was based on children born between the years of 1972 and 1985. Over 85% of the researchers utilized a longitudinal, prospective design in which the children were located at birth and their parents were asked to participate in long-term research on the outcome of low birthweight infants.

Table 2

Characteristics of Studies Used in Sample

	Mean	Minimum	Maximum
# Comparisons per Study			
Year of Publication	1986	1976	1991
Year Data Began	1978	1960	1985
Year Data Ended	1980	1962	1988
		Percent	umber of Groups
Site of Study			
Australia		17.8	40
Canada		7.6	17
England		6.7	15
Europe		9.8	22
USA		56.9	123
Other		1.3	3
		Percent	umber of Groups
Length and Type of Study			
Longitudinal, Prospective		85.8	193
Longitudinal, Retrospective		2.2	5
Single measure, Prospective		5.8	13
Single measure, Retrospective		4.9	11
No way to tell		1.3	3

Validity ratings. All studies were rated on several aspects of the research validity in order to assess the degree to which the results might be generalized to those infants not included in the sample. Mean ratings on each of the validity factors examined are listed in Table 3. One of the most important aspects of validity has to do with the examiners' knowledge of the birthweight status of the child being assessed, as well as the hypotheses being tested. On this item, most of the studies were designed carefully, such that the experimenter could be considered "blind." However, over 33% of the studies did not include enough information to make a assessment on this aspect of design. The other most salient validity concerns were subject selection procedures and mortality of subjects. Almost 60% of the studies used either random sampling procedures or included all infants born who met their inclusion criteria and

Table 3

Validity Ratings

	Mean Rating	Minimum Score	Maximum Score
Validity Items			
Experimenter Bias	0.4	0	3
Maturation	0.1	0	1
History	0.2	0	3
Testing	0.3	0	3
Instrumentation	0.1	0	3
Regression to the Mean	0.0	0	0
Selection	0.6	0	3
Mortality	0.9	0	3
Overall Study Quality	2.4	1	5
Description of Subjects	2.3	1	3

survived past the neonatal period. Many included information on those children who subsequently died, but had initially been part of the sample. Subject mortality, in the form of attrition, created more problems for the researchers. Only 32% of the studies were considered to have adequately followed up on the original sample at each later assessment period. Another 36% had mild problems with attrition, while 25% had potentially significant difficulty in attributing their conclusions to the fact the sample was LBW rather than attrition of the sample.

Characteristics of the Infants

Fullterm controls compared to LBW infants. While the majority of the studies compared the LBW infants to test norms, occasionally the research design included a control group of fullterm infants, often matched on such characteristics as socioeconomic status or geographical region of birth and schooling. There were 66 fullterm control groups used, in which the average sample size was 55. The mean gestational age was 40 weeks and the average birthweight was 3386 grams. The apgar scores for fullterm infants were seldom reported, but when given, were significantly higher than for the LBW infants (about 8.3 at 1 minute and 9.4 at 5 minutes).

To be considered LBW, infants had to weigh less than 2,500 grams at birth. Almost half of the infants were a combination of those born at a neonatal intensive care

center and those who were transported to the centers after birth (Table 4). The average sample size was 49. Within the samples, the average gestational age was 30 weeks and mean birthweight was 1316 grams. The average 1-minute apgar score was 4.8, while the 5-minute average was 7.0.

Perinatal complications. A attempt was made to determine the presence of perinatal complications among the LBW infants, particularly those which might have an effect on their outcome. Table 5 lists the reported percentages of the complications most frequently discussed in relation to intraventricular hemorrhage among the LBW infants. However, as can be seen by the umber of studies which provided this type of information, the figures cannot be used as a epidemiological sample. Very few researchers reported complete medical data on their sample. This information

Table 4

Sample Characteristics

	Fullterm Sample		LBW Sample	
	Mean		Mean	
Sample Size	54.7	66	48.9	225
Gestational Age	39.9	64	30.0	186
Birth Weight	3386.3	55	1315.7	174
1 Minute Apgar			4.8	42
5 Minute Apgar			7.0	55
Socioeconomic Status	3.3	19	3.3	31
Location of Birth:				
Inborn			19.1	43
Mixed			44.4	100
Outborn			14.2	32
Not Specified			22.2	50

Table 5

Rate of Perinatal Complications Among Entire Sample

	Fullterm Sample		LBW Sample	
	Mean	# of Groups Reporting Information	Mean	# of Groups Reporting Information
Bronchopulmonary Dysplasia (BPD)	0.0	23	20.4	39
Patent Ductus Arteriosus (PDA)	0.0	20	28.4	23
Respiratory Distress Syndrome (RDS)	0.1	36	74.2	105
Pneumothorax	0.0	25	29.4	19
Apnea/Asphyxia	0.0	22	48.1	48
Thrombocytosis	0.0	16	0.0	1
Pneumonia	0.0	16	18.0	7
Acidosis	0.0	17	33.3	17
Seizures	0.0	21	14.6	45
Hydrocephalus	0.0	24	26.7	53
Sepsis	0.0	15	17.2	25
Gen Med Complications	6.1	20	32.5	15

became more scarce as the age at assessment increased.

When comparing the fullterm control infants to the LBW infants, a similar caveat must be issued. In most cases the fullterm infants were picked to specifically exclude those with any medical complications. When a more random sample of fullterm infants was used, the incidence of medical complications was provided in fewer than 30% of the studies.

As with the reporting of medical complications in general, the figures on intraventricular hemorrhage were often incomplete (Table 6). However, among the fullterm infants, it was specifically excluded, or could be assumed to be, due to the extremely low incidence of this condition among fullterm babies. Most of the data on the LBW

Table 6

Incidence/Reported Rate of Intraventricular Hemorrhage (IVH)by Grade

	Fullterm Sample		LBW Sample	
	Percent		Percent	
Excluded	100	66	15.1	34
Grade I			4.0	9
Grade in & II			4.9	11
Grade II			4.9	11
All Grades			55.5	125
Grade II & III			0.9	2
Grade III			4.9	11
Grade III & IV			5.8	13
Grade IV			4.0	9

infants did not specify how many of the babies had a brain hemorrhage. Even when this was reported, the grade of hemorrhage was seldom provided.

Characteristics and perinatal complications by birthweight grouping. Because of the prognostic importance of birthweight, the LBW sample was grouped by birthweight, using those traditionally endorsed by researchers. As can be seen in Tables 7 and 8, the heavier infants were typically older, had higher apgar scores, and fewer reported medical complications. The exception to this trend was among the infants weighing 2000 grams or more. Because of the small number of studies in which the mean birthweight was this heavy, this result is most likely a artifact of the small sample size and inconsistent reporting of this information. For example, in the population as a whole,

Table 7

Low Birthweight Infant Sample Characteristics by Birthweight Grouping

	LT 1000 Grams		1000-1250		1251-1500		1501-2000		2001+ Grams	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Sample Size	32.0	105	50.2	261	37.4	91	51.0	117	93.6	57
Gestational Age	27.4	99	29.8	245	30.4	89	32.3	110	31.5	57
Birth Weight	885.5	105	1122.7	261	1330.4	91	1735.5	117	3241.2	57
1 Minute Apgar	4.1	41	5.0	57	5.5	20	5.5	31	4.9	6
5 Minute Apgar	6.1	41	7.2	79	7.1	20	7.6	39	6.3	11
Hollingshead	3.3	31	3.5	91	3.5	11	3.1	30	2.5	7

	LT 1000 Grams		1000-1250		1251-1500		1501-2000		2001+ Grams	
	Percent	N	Percent	N	Percent	N	Percent	N	Percent	N
Birth Location:										
Inborn	22.9	24	5.7	15	19.8	18	6.8	8	5.3	3
Mixed	38.1	40	41.0	107	41.8	38	55.6	65	40.4	23
Outborn	31.4	33	36.4	95	14.3	13	11.1	13	10.5	6
Not Specified	7.6	8	16.9	44	24.2	22	26.5	31	43.9	25

Table 8

Low Birthweight Infant Perinatal Complications by Birthweight Grouping

	LT 1000 Grams		1000-1250		1251-1500		1501-2000		2001+ Grams	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
BPD	24.8	6	24.4	112	16.0	28	0.0	6	0.0	9
PDA	52.7	7	13.4	24	20.3	10	2.0	7	No data	
RDS	74.3	21	75.2	182	76.9	75	53.6	20	60.4	10
Pneumothorax	62.5	2	18.8	13	33.7	23	16.8	24	No data	
Apnea/Asphyxia	59.0	25	52.8	74	40.3	23	9.6	28	43.3	9
Thrombocytosis	No data		No data		No data		No data		No data	
Pneumonia	No data		No data		30.0	3	0.0	6	No data	
Acidosis	38.0	3	40.9	14	32.0	19	0.0	4	95.2	5
Seizures	11.8	20	13.5	43	19.1	31	4.3	8	39.0	6
Hydrocephalus	10.7	15	18.6	100	44.8	28	4.2	24	No data	
Sepsis	14.6	9	24.0	27	6.9	16	10.5	6	No data	
Gen Complica.	No data		59.8	8	16.0	8	32.5	6	17.9	17

those infants weighing over 2000 grams are not more likely than infants of lower birthweight to have acidosis, apnea, or seizures.

The data for the reported rate of IVH broken down by birthweight group are presented in Table 9. Due to the lack of sufficient information, it is difficult to clearly see the relationship between birthweight and incidence, although this has been strongly demonstrated elsewhere (Volpe, 1987).

Characteristics and perinatal complications by IVH grade. A overview of the sample characteristics suggests there is not a relationship between severity of IVH and gestational age (all grades tended to be prominent within the 29-30 week range), birthweight (1000 to 1500 gram range), apgar scores, or socioeconomic status (Table 10). It is unclear as to whether these results might be an artifact of the lack of sufficient information on these variables in most of the outcome studies.

Data on perinatal complications broken donw by grade of IVH were so sparse as to be difficult to discuss (Table 11). The two groups with significant numbers were those in which infants with IVH were either specifically excluded or combined all IVH grades (which also included infants who did not have an IVH). However, as in the general population of LBW infants, those without IVH had significantly fewer medical complications than did the group comprised of all IVH grades.

Table 9

Incidence/Reporting of Intraventricular Hemorrhage in the Low Birthweight Sample

	LT 1000 Grams		1000-1250		1251-1500		1501-2000		2001+ Grams	
	Percent	N	Percent	N	Percent	N	Percent	N	Percent	N
Excluded	4.8	5	21.5	56	13.2	12	25.6	30	15.8	9
Grade I	1.9	2	1.1	3	1.1	1	No subjects		No subjects	
Grade I & II	9.5	10	5.0	13	9.9	9	6.0	7	No subjects	
Grade II	1.9	2	1.9	5	1.1	1	0.9	1	No subjects	
All Grades	68.6	72	60.5	158	47.3	43	61.5	72	84.2	44
Grade II & III	No subjects		0.8	2	2.2	2	No subjects		No subjects	
Grade III	11.4	12	3.4	9	No subjects		6.0	7	No subjects	
Grade III & IV	No subjects		3.4	9	16.5	15	No subjects		No subjects	
Grade IV	1.9	2	2.3	6	8.8	8	No subjects		No subjects	

Table 10

Sample Characteristics by Grade of Intraventricular Hemorrhage

	IVH Excluded		Grade I		Grade I & II		Grade II		All Grades	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Sample Size	31.9	133	16.8	16	29.7	13	15.0	19	68.2	332
Gestational Age	30.9	122	29.9	10	30.0	45	29.7	13	30.0	294
Birth Weight	1367.5	112	1069.7	6	1234.1	39	1206.7	9	1405.7	274
1 Minute Apgar	4.9	32	4.6	4	4.5	16	4.3	4	5.3	85
5 Minute Apgar	6.8	39	7.1	4	6.4	16	7.2	6	7.5	104
SES	3.5	27	No data		3.6	11	No data		3.2	95

	Grade II & III		Grade III		Grade III & IV		Grade IV	
	Mean	N	Mean	N	Mean	N	Mean	N
Sample Size	12.0	4	12.3	32	20.1	39	16.5	20
Gestational Age	29.5	4	29.1	28	29.8	34	29.1	16
Birth Weight	1246.5	4	1146.4	28	1256.3	24	1169.7	16
1 Minute Apgar	No data		4.4	19	4.4	4	4.4	9
5 Minute Apgar	8.0	2	6.6	21	6.5	4	6.7	9
SES	No data		No data		3.5	11	No data	

Table 11

Perinatal Complications by Grade of Intraventricular Hemorrhage

	IVH Excluded		Grade I		Grade I & II		Grade II		All Grades	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
BPD	9.8	49	No data		9.7	17	26.0	2	25.5	96
PDA	17.7	9	0.0	1	No data		0.0	1	27.0	54
RDS	80.0	52	89.7	6	90.1	18	86.3	7	65.8	213
Pneumothorax	15.3	16	34.0	1	0.0	6	72.0	1	12.5	32
Apnea/Asphyxia	28.1	39	86.0	1	No data		52.5	2	45.3	139
Pneumonia	10.0	9	No data		No data		14.0	1	23.0	24
Acidosis	0.0	3	0.0	1	No data		0.0	1	46.7	57
Seizures	5.9	16	27.7	3	No data		0.0	3	14.0	110
Hydrocephalus	0.6	55	6.3	3	0.0	12	36.5	6	17.1	94
Sepsis	9.6	14	No data		No data		No data		20.1	62
Gen Complica.	26.7	27	No data		No data		No data		36.0	36

	Grade II & III		Grade III		Grade III & IV		Grade IV	
	Mean	N	Mean	N	Mean	N	Mean	N
BPD	21.0	2	26.0	2	13.8	17	No data	
PDA	No data		14.0	1	33.0	3	0.0	1
RDS	54.0	2	82.8	8	84.4	23	90.3	6
Pneumothorax	No data		50.0	6	29.5	43	0.0	6
Apnea/Asphyxia	No data		44.0	1	No data		71.0	1
Pneumonia	No data		No data		No data		No data	
Acidosis	No data		0.0	1	No data		0.0	1
Seizures	No data		24.0	3	No data		36.3	3
Hydrocephalus	57.0	2	65.8	4	76.4	17	46.5	2
Sepsis	0.0	2	No data		0.0	2	No data	
Gen Complica.	0.0	2	No data		0.0	2	No data	

Outcome Measures

Age at assessment. The data on the age at which most assessments were conducted can be found in Table 12. One of the most pertinent facts found in this table is that testing was seldom done past the age of 6. The only exception to this trend is in the area of academic ability, which obviously cannot be done prior to school age. Cognitive or developmental testing was done fairly regularly across all ages until the children were 6 and older. As would be logically expected, speech and language assessment were not done as frequently in the very young children. However, the most testing was done in the 2-1/2- to 3-year range, well before language development is complete.

Fine motor assessment was done equally across all age ranges, once the children were out of infancy, giving relatively good information regarding this area of development. The same cannot be said for the area of gross motor skills. Over 95% of the assessment of gross motor skills occurred before the children were 2 years of age, well before the development of such skills is complete.

When looking at the data on personality and temperament, it is important to note that while what most researchers termed personality assessment was conducted fairly regularly at all ages, temperament seemed to be a term that was considered most applicable among infants

Table 12

Percent of Assessments Done at Specific Ages

		Cognitive Developmt	Academic	Speech Language	Fine Motor	Gross Motor	Person-ality	Temper-ament	Total
LT 9 Months	Row Pct	44 39.2%	NA	1 0.9%	0	28 25.0%	1 0.9%	38 33.9%	112 17.8%
	Col Pct	14.2%		1.8%		22.2%	1.9%	74.5%	
9 to 12 Months	Row Pct	59 50.4%	NA	4 3.4%	4 3.4%	29 24.8%	12 10.3%	9 7.7%	117 18.6%
	Col Pct	19.1%		7.1%	15.4%	23.0%	23.1%	17.6%	
15 to 21 Months	Row Pct	38 44.7%	NA	10 11.8%	2 2.4%	27 31.8%	8 9.4%	0	85 13.5%
	Col Pct	12.3%		17.9%	7.7%	21.4%	15.4%		
22 to 24 Months	Row Pct	62 49.2%	NA	15 11.9	3 2.4%	37 29.4%	9 7.1%	0	126 20.0%
	Col Pct	20.1%		26.8%	11.5%	29.4%	17.3%		
30 to 38 Months	Row Pct	19 38.8%	NA	18 36.7%	4 8.2%	3 6.1%	5 10.2%	0	49 7.8%
	Col Pct	6.1%		32.1%	15.4%	2.4%	9.6%		
42 to 63 Months	Row Pct	39 70.9%	NA	5 9.1%	6 10.9%	0	5 9.1%	0	55 8.7%
	Col Pct	12.6%		8.9%	23.1%		9.6%		
6 to 8 Years	Row Pct	17 50.0%	0	0	3 8.8%	2 5.9%	8 23.5%	4 11.8%	34 5.4%
	Col Pct	5.5%			11.5%	1.6%	15.4%	7.8%	
8 to 11 Years	Row Pct	31 60.8%	9 17.6%	3 5.9%	4 7.8%	0	4 7.8%	0	51 8.1%
	Col Pct	10.0%	100.0%	5.4%	15.4%		7.7%		
Total	Col Pct	309 49.1%	9 1.4%	56 8.9%	26 4.1%	126 20.0%	52 8.3%	51 8.1%	629 100.0%

and/or very young children and only assessed while the children were very young.

In order to assess the effects of IVH on outcome, it was considered important to define the subject groups by severity of the hemorrhage. The system developed by Papile et al. (1978) is that most frequently used in the literature. According to this classification system, a Grade I hemorrhage is defined as a subependymal hemorrhage, which often diminishes in 1 week and disappears from CT scans by 3 weeks of age. Grade II hemorrhages are those which bleed into the ventricles but do not cause ventricular dilation. Grade III hemorrhages involve ventricular dilation, while Grade IV bleeds include parenchymal hemorrhage and ventricular enlargement. Often children with a Grade III or IV hemorrhage will experience post-hemorrhagic hydrocephalus, requiring ventricular shuts.

Breakdowns of the area of assessment by grade/severity of hemorrhage and age at testing can be found in Tables F-1 through F-7, located in Appendix F. A summary of these tables can be found in Table 12. The most significant findings from these tables are:

1. Aside from the areas of cognitive/developmental and gross motor ability, very little information is given on how severity of IVH may affect the child's ability in a given area. There are a limited number of studies which assessed the children's gross motor skills in comparison to the

severity of brain hemorrhage they experienced. Despite this limitation, these studies are well distributed across the range of IVH severity, providing a reasonably stable data base from which to draw conclusions. However, this is only true for assessments done prior to the age of 42 months. After that, there were only two studies done, either of which provided information on the perinatal characteristics of their sample.

2. There has been virtually no academic assessment of these children.

3. By the time the subjects were 6 and older, most researchers did not include information on perinatal status and medical complications, making it nearly impossible to assess the long-term effects of the hemorrhages. This is particularly true when one questions the effects of hemorrhages on more "subtle" difficulties, such as learning disabilities, language disorders, attentional deficits, and behavioral problems.

4. Under the coding system used to collect these data, information on behavioral problems among these children was classified in both the personality and temperament domains. In Table 12 the reader can quickly see there is virtually no information on these children as infants and only little more regarding the school-age behavior/personality of these children. Virtually no measures of temperament were taken after the age of 1 year. This paucity of data makes it

nearly impossible to predict the prevalence of behavioral disorders. In addition, the DSM III-R requires the observation of such behaviors when the child is at least of preschool age in order to diagnose such disorders as Attention Deficit Hyperactivity Disorder, Oppositional Defiant Disorder, or Conduct Disorder.

5. Comparisons of personality and temperament functioning (mean effect sizes) in the LBW children could not be done in any meaningful manner. The major problem with this data base is the difficulty in interpreting the scores, since an extreme score in any direction could indicate behavioral problems. Further, adequate psychometric properties and test norms were not typically available and control groups were seldom used. The results from this analysis can be found in Appendix G, but no interpretation can be provided, due to the problems mentioned above.

Standard of comparison. As mentioned earlier, the comparison statistic for this study is the mean effect size, which converts all outcome measures to a common metric. For the purposes of this analysis, the standard of comparison was either the published population norms for a given assessment device or the score from a control group. In order to assess the comparability of these two deferred comparison groups, *t* tests were done on each of the areas of

Table 13

Comparison of Effect Sizes by the Use of Population Norms Versus Control Group Scores

	Cognitive Developmt	Academic	Speech/ Language	Fine Motor	Gross Motor
Fullterm Controls					
Mean	.60[a]	.66[b]	.81[c]	.91[d]	.94
N	112	2	44	22	21
Population Norms					
Mean	.46[a]	.16[b]	.35[c]	.65[d]	.87
N	197	7	12	4	106

Note. Same letter superscript indicates means were significantly different ($p < .004$).

outcome. As can be see in Table 13, those preterm infants who were compared to matched controls showed significantly more impairment on measures of cognition, academic skill, speech/language ability, and fine motor skills. The only area to maintain comparability was the gross motor domain.

With the exception of speech and language assessment studies, the majority of studies did not use a matched control group design. It follows that most of the results presented below will significantly overestimate the actual ability of the LBW infants and children in all areas except language. For example, in the area of cognition, while 112 studies utilized a matched control group, 197 presented their data as compared to population norms. Thus, the mean effect size will be a underestimate of the deficits these children display as they mature in all areas except gross

motor skills.

Cognitive/developmental functioning. As the majority of studies included some measure of cognition or developmental status, there were far more groups available for this analysis (N = 309) than the other areas of assessment. As can be seen in Table 14, LBW infants and children tend to score about 1/2 standard deviation below the comparison group, whether it is the population norms (2/3 of the time) or a matched control group (1/3 of the time). Effect sizes ranged from .15 to 1.01, based on the age of assessment. There were not any trends in how impaired the children were based on age of assessment. That is, they did not seem to display more or less difficulty as they aged.

When the data are broken down by IVH grade, it can be clearly seen that there is an inverse relationship ($r = .41$, $p < .0005$): those infants without any type of brain hemorrhage had higher cognitive scores than did those who with any type of hemorrhage. Those without hemorrhages compared favorably with the comparison group (about 10% of a standard deviation below, which is within the standard error of measurement for all the tests). However, as the severity of hemorrhage increased, cognitive scores decreased (Grades I and II were 46% of a standard deviation below, all grades combined were 65% of a standard deviation lower, and Grades

Table 14

Mean Effect Size of Cognitive/Developmental Quotient Differences by Grade of Hemorrhage and Age at Measurement

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Total Sample
LT 9 Months	Mean	.30	.50	.74	1.14	.62
	Std Dev	.74	.85	.77	.88	.81
	N	14	7	17	6	44
9 to 12 Months	Mean	-0.13	.28	.43	1.32	.42
	Std Dev	.72	.63	.63	1.15	.87
	N	14	11	24	10	59
15 to 21 Months	Mean	.04	.44	.97	.84	.57
	Std Dev	.52	.93	.83	.73	.81
	N	11	7	9	11	38
22 to 24 Months	Mean	.23	.49	.73	1.29	.72
	Std Dev	.40	.51	.59	.77	.66
	N	8	11	32	11	62
30 to 38 Months	Mean	.49	.89	.97	2.07	1.01
	Std Dev	.61	.19	.59	.46	.73
	N	5	2	9	3	19
42 to 63 Months	Mean	-0.03	.55	.54	.60	.51
	Std Dev	.06	.93	.51	.84	.65
	N	3	6	21	9	39
6 to 8 Years	Mean			.15		.15
	Std Dev			.25		.25
	N			17		17
8 to 11 Years	Mean			.46		.46
	Std Dev			.51		.51
	N			31		31
Total	Mean	.13	.46	.65	1.10	.56
	N	55	44	160	50	309

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

III and IV were slightly more than a standard deviation below). This relationship was consistent across ages at assessment.

Academic achievement. The data obtained for this analysis are presented in Table 15. The most striking feature of this table is the dearth of data available. There have been very few studies which address how LBW children perform academically, particularly as they compare to their normal peers. None of these studies include information on the neonatal status of these children, nor were there data on the presence/severity of brain hemorrhage. Based on the data available, the LBW children seem to perform about 1/2 standard deviation behind their peers. This conclusion needs to be tempered by the fact that a number of these studies specifically excluded children with severe handicapping conditions or only assessed those children who had been placed in regular educational settings.

Speech and language abilities. The results of the speech and language assessments are listed in Table 16. There were relatively few studies found assessing early language development (less than 15 months of age). Those done indicate the LBW infants compare well to both peers and test norms. However, delays became evident by the time the children were 15 months of age, and the children seem to fall further behind, up to the age of about 4 years. It

Table 15

Mean Effect Size of Academic Ability by Grade of Hemorrhage and Age at Measurement

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Total Sample
LT 9 Months	Mean					
	Std Dev					
	N					
9 to 12 Months	Mean					
	Std Dev					
	N					
15 to 21 Months	Mean					
	Std Dev					
	N					
22 to 24 Months	Mean					
	Std Dev					
	N					
30 to 38 Months	Mean					
	Std Dev					
	N					
42 to 63 Months	Mean					
	Std Dev					
	N					
6 to 8 Years	Mean					
	Std Dev					
	N					
8 to 11 Years	Mean			.52		.52
	Std Dev			.62		.62
	N			9		9
Total	Mean			.52		.52
	N			9		9

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

Table 16

Mean Effect Size of Speech/Language Skills by Grade of Hemorrhage and Age at Measurement

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Total Sample
LT 9 Months	Mean	.01				.01
	Std Dev	.00				.00
	N	1				1
9 to 12 Months	Mean			-0.11		-0.11
	Std Dev			.89		.89
	N			4		4
15 to 21 Months	Mean	.67		.28		.56
	Std Dev	1.14		.49		.98
	N	7		3		10
22 to 24 Months	Mean	.41	.79	.68	.90	.67
	Std Dev	.37	.00	.84	.00	.73
	N	2	1	11	1	15
30 to 38 Months	Mean	1.13	1.13	.93	1.21	1.06
	Std Dev	.26	.13	.81	.12	.54
	N	3	3	8	4	18
42 to 63 Months	Mean	-0.20	-0.30	.94	-0.20	.01
	Std Dev	.00	.00	.00	.42	.56
	N	1	1	1	2	5
6 to 8 Years	Mean					
	Std Dev					
	N					
8 to 11 Years	Mean			.11		.11
	Std Dev			.05		.05
	N			3		3
Total	Mean	.62	.78	.55	.76	.62
	N	14	5	30	7	56

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

is difficult to make any predictions beyond this age, due to the lack of data. It is unknown how these children master more complex language skills when they are school-age.

Contrary to the data on cognitive ability, speech/language capabilities did not seem to be affected by either the presence or severity of brain hemorrhages ($r = .02$, $p < .50$). Overall, the LBW children were nearly two-thirds of standard deviation behind their peers in their comprehension and expression of language.

Fine motor skills. In looking at the results of fine motor assessment (Table 17), the first fact to be noticed is the small number of studies which addressed this area of development. Only 26 studies were found which measured some aspect for fine motor ability. Given such a small sample, it is difficult to draw conclusions regarding age of assessment or effect of brain hemorrhages.

When looking at the average effect size difference, the most striking piece of information is that there seems to be remarkable variability, with a range of scores from -0.30 (preterm children scoring one-third standard deviation higher than fullterm children) to 2.22 (preterm children scoring over 2 standard deviations behind the comparison group). While the mean effect sizes show less variability when broken down by grade of hemorrhage, there is still a wide range of deviation (0.50 to 1.09) and seems to be no relationship between the two ($r = -.05$, $p < .413$). Overall,

Table 17

Mean Effect Size of Fine Motor Skills by Grade of Hemorrhage and Age at Measurement

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Total Sample
LT 9 Months	Mean					
	Std Dev					
	N					
9 to 12 Months	Mean			-0.30		-0.30
	Std Dev			.98		.98
	N			4		4
15 to 21 Months	Mean	1.34				1.34
	Std Dev	.77				.77
	N	2				2
22 to 24 Months	Mean	.09		.67		.47
	Std Dev	.00		.49		.48
	N	1		2		3
30 to 38 Months	Mean	1.89	1.73	2.90	2.36	2.22
	Std Dev	.00	.00	.00	.00	.53
	N	1	1	1	1	4
42 to 63 Months	Mean	.20	-0.10	.47	.45	.32
	Std Dev	.00	.00	.11	.35	.28
	N	1	1	2	2	6
6 to 8 Years	Mean			.30		.30
	Std Dev			.13		.13
	N			3		3
8 to 11 Years	Mean			.78		.78
	Std Dev			.17		.17
	N			4		4
Total	Mean	.97	.82	.50	1.09	.68
	N	5	2	16	3	26

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

LBW children scored consistently below the comparison group on fine motor abilities.

Gross motor skills. Gross motor ability was the second most common developmental area assessed. However, 96% of this testing was done prior to the age of 24 months. Only 4% of the time was gross motor ability assessed after that age. It is interesting to note that as the children aged, the data suggest they showed increasing deficits in this area, up to the age at which testing was no longer done (about 3 years old). As with speech and language abilities, there is no information regarding gross motor skills in these children as they grow older.

In looking at the effect of IVH on gross motor skills (Table 18) one sees a strong inverse relationship ($r = .65$, $p < .0005$), similar to that found in the data on cognitive abilities. Those children without a hemorrhage had the least amount of delay in gross motor skills, being about one-fourth of a standard deviation behind the comparison group. As the severity of the hemorrhage increased, so did the amount of delay, such that those with the most severe bleeds were nearly 1-2/3 standard deviations behind.

Summary

The data used in this meta-analysis consisted of 125 published studies which assessed outcome for 309 separate groups of low birthweight infants and children. The

Table 18

Mean Effect Size of Gross Motor Skills by Grade of Hemorrhage and Age at Measurement

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Row Total
LT 9 Months	Mean	.28	.25	.96	1.12	.69
	Std Dev	.75	.48	.99	.16	.84
	N	7	5	12	4	28
9 to 12 Months	Mean	.28	.71	1.09	1.88	.95
	Std Dev	.39	.51	.64	1.06	.82
	N	7	6	11	5	29
15 to 21 Months	Mean	.20	.65	1.47	1.38	.90
	Std Dev	.30	.40	.78	.48	.76
	N	9	4	7	7	27
22 to 24 Months	Mean	.17	.80	.88	1.75	.92
	Std Dev	.25	.64	.53	1.00	.81
	N	7	7	15	8	37
30 to 38 Months	Mean	.31	1.06		3.13	1.50
	Std Dev	.00	.00		.00	1.46
	N	1	1		1	3
42 to 63 Months	Mean					
	Std Dev					
	N					
6 to 8 Years	Mean			.61		.61
	Std Dev			.22		.22
	N			2		2
8 to 11 Years	Mean					
	Std Dev					
	N					
Total	Mean	.23	.64	1.03	1.63	.88
	N	31	23	47	25	126

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

majority of the children were born in developed countries between 1972 and 1985.

Most of the studies compared LBW infants to test norms, while about one-third of the comparisons utilized a matched control group design. In comparing the LBW infants to the fullterm controls, the LBW infants experienced significantly more perinatal complications. Fullterm controls were often chosen based on the absence of perinatal complications, particularly IVH.

Data on perinatal complications among the LBW infants were broken down by birthweight. As expected, heavier infants were born older and healthier. Less information was available on the presence of IVH, due to incomplete reporting of this complication.

Researchers most commonly assessed the children's cognitive abilities when measuring outcome. The next most common area of measurement was gross motor skills. Fine motor abilities and speech and language skills were evaluated enough that some general conclusions can be made regarding outcome in these areas. Academic skills were very seldom measured and when it was done, there were no comparisons by grade of IVH. Personality and temperament measures were also infrequent.

Mean effect sizes were computed by comparing the LBW group to either a fullterm control group or to the test norms. However, these comparison groups are not equivalent:

when compared to fullterm control children, the LBW children scored significantly worse in the areas of cognition, academic achievement, speech and language skills, and fine motor ability. The single exception to this finding was in the area of gross motor skills, where there were not significant differences between the scores of the LBW children who were compared to test norms versus a control group.

Cognitive assessment was done equally at all ages up to the age of 6 years. At that time, far fewer evaluations were performed. When done, there was not information on specific perinatal complications given. Overall, LBW children scored about one-half of a standard deviation below their comparison group on cognitive measures. However, this result was strongly mediated by the presence and severity of a brain hemorrhage. The more severe the bleed, the more cognitive impairment seen among these children. Those children without an IVH scored comparably to the comparison group, while those with severe bleeds were about a full standard deviation behind.

Assessment of academic skills was only done in the 8- to 11-year age range and there was no information given on perinatal complications. Academically, the LBW children scored about one-half of a standard deviation behind the comparison group. However, there were so little data available on academic achievement that it is unknown how

these results apply to children with and without IVH.

Over 80% of the speech and language assessments were done between the ages of 15 to 38 months. LBW children tended to score anywhere from one-half to three-quarters of a standard deviation below the comparison group. Surprisingly, the severity of hemorrhage did not mediate these results.

Fine motor assessment was not done as commonly. Assessments were spread out over the ages of 9 months to 11 years. LBW children as a whole were slightly more than two-thirds of a standard deviation behind the comparison group. As with speech and language abilities, fine motor skills did not seem to be affected by the presence or severity of IVH. However, given the small sample sizes in this analysis, these results need to considered cautiously.

Substantially more evaluations were performed on the LBW children's gross motor abilities. However, over 95% of the testing was done when the children were 24 months old or less. Overall, these children showed more significant deficits in this area than in any other: almost 90% of a standard deviation behind. As with cognitive functioning, gross motor skills appear to be strongly impacted by both low birthweight and the presence and severity of IVH. The more severe the bleed, the greater the impairment manifested by these children, such that those with Grades III and IV hemorrhages displayed fairly severe gross motor delays. A

summary of the mean effect sizes for all areas of assessment can be found in Table 19.

Table 19

Summary Table: Mean Effect Sizes by Age at Assessment

		Cognitive Developmt	Academic	Speech Language	Fine Motor	Gross Motor	Person-ality	Temper-ament
LT 9 Months	Mean	.62		.01		.69	.32	.23
	Std Dev	.81				.84		.68
	N	44		1		28	1	38
9 to 12 Months	Mean	.42		-0.11	-0.30	.95	.08	
	Std Dev	.87		.89	.98	.82	.96	
	N	59		4	4	29	12	
15 to 21 Months	Mean	.57		.56	1.34	.90	1.86	
	Std Dev	.81		.98	.77	.76	1.46	
	N	38		10	2	27	8	
22 to 24 Months	Mean	.72		.67	.47	.92	.32	
	Std Dev	.66		.73	.48	.81	.43	
	N	62		15	3	37	9	
30 to 38 Months	Mean	1.01		1.06	2.22	1.50	1.38	
	Std Dev	.73		.54	.53	1.46	.40	
	N	19		18	4	3	5	
42 to 63 Months	Mean	.51		.01	.32		.61	
	Std Dev	.65		.56	.28		.29	
	N	39		5	6		5	
6 to 8 Years	Mean	.15			.30	.61	.61	
	Std Dev	.25			.13	.22	.26	
	N	17			3	2	8	
8 to 11 Years	Mean	.46	.52	.11	.78		.96	
	Std Dev	.51	.62	.05	.17		.11	
	N	31	9	3	4		4	
Total	Mean	.56	.52	.62	.68	.88	NA	NA
	Std Dev	.73	.62	.71	.91	.91		
	N	309	9	56	26	126	52	38

Note. Positive effect sizes indicate the fullterm groups performed better than the preterm group or that the population norms were higher than the preterm groups' scores. N refers to the number of comparisons for that age and grade of hemorrhage.

CHAPTER VI

DISCUSSION

Conclusions

Based on the results from this meta-analysis, it seems that LBW infants without brain hemorrhages show very mild cognitive deficits, which are well within the standard error of measurement for the assessment devices used (about 2 IQ points for such tests as the WISC-III). However, LBW children with IVH show significantly more deficits, and the deficits become more severe with larger sized hemorrhages, such that those with Grades III or IV hemorrhage will score, on average, a full standard deviation below the mean (in what is often termed the "low average range"). While this deficit may not qualify a child as being intellectually handicapped, it is probable that s/he will require additional services in order to function within a school setting.

One of the most disappointing findings in this study was the lack of assessment of academic skills. Only nine studies were found which presented their data in such a way that it could be quantified for this study. All those studies evaluated children in the 8- to 11-year range. The LBW children scored about 1/2 standard deviation behind their peers, which places them in the 20th to 30th percentile in their classes. There were not enough studies to learn of abilities within the specific areas of

academics, such as reading, written language, and mathematics.

Speech and language assessments were primarily done prior to a child's entrance into school (up to age 38 months). The LBW children displayed deficits which are not mediated by the presence of brain hemorrhages. These deficits tend to place the children between the 15th to 30th percentiles when comparing them to same-age peers. Thus, while they show delays in speech and language acquisition, the deficits are not typically severe enough to warrant preschool intervention. There was no information for this study on how these children develop language skills as they age. Given the increasing complexities of language acquisition, it is likely these children show varying degrees of communication disorders, beyond what would be expected in the general population.

Fine motor skills were more globally delayed than other skill domains in all the LBW children. The results indicate these children are typically functioning anywhere from the 10th to the 30th percentile. In everyday functioning this area tends to be more subtle, with few direct difficulties and even fewer interventions. Given the lack of data, it remains to be seen how the children perform in this area as they age, particularly if they experienced an IVH.

Gross motor assessment, while the second most frequent outcome measured, was seldom done past the age of 24 months.

Up to that time, there is a very strong relationship between severity of hemorrhage and degree of delay. Those children with the most severe hemorrhages ranked well below the 10th percentile in ability. It is interesting to note that in this area, population norms were comparable to the results from matched control groups. By way of explanation, it may be that the gross motor domain is less affected by environmental stimuli than other areas of assessment. For example, it is known that over the years, intelligence tests need to be normed again because the average score moves from 100 to something over that. It would seem that the norms for gross motor functioning, particularly in the infancy and toddler stages, remain more reliable than those for the other areas.

Practical Implications

The above research has several implications for how the needs of this growing population might be met.

1. In order to begin early intervention treatment and planning for special educational needs of these children, the timely identification of infants at-risk for developmental delays is crucial (Bennett, 1987). Based on this study the following conclusions could be suggested:

   a. LBW infants should all be considered at risk for certain difficulties, such as motor delays, even when the correction for prematurity is used.

   b. Those infants with any grade of hemorrhage are

at increased risk for delays, particularly in the areas of cognition and gross motor abilities.

2. Because it can reasonably be assumed that deficits in any of these areas (speech, fine motor, gross motor, etc.) would be present in a continuum of ability ranging from severe to above average, it seems likely that these children are at increased risk for less obvious problems, such as learning disabilities and communication disorders.

3. Parents with LBW infants could learn to provide intervention early on so as to offset difficulties as soon as possible.

4. School administrators need to be planning for the additional number of LBW children who survive the neonatal period and will most likely present with mild to severe deficits.

Future Research

Questions that remain. There were several questions unanswered by this research. Across all areas, there is no information on these children as they reach adolescence, and very little data on them in the elementary school years. This is particularly true of their academic achievement. In the areas of speech/language and gross motor skills, there is virtually no research past the preschool ages.

An area of growing concern among educators is the behavior of children and how that affects their ability to function in school. One of the initial goals of this

project was to learn of the relationship (if any) between a somewhat quantifiable neurological insult (IVH) and later behavior, such as attention span, aggression, depressive symptoms, and hyperactivity. After thoroughly reviewing the literature, virtually no research which addressed this issue was found. Obviously this is an area of tremendous need for research.

When research has been done on school-age children, prenatal and perinatal data are seldom provided. Thus, there is no way to determine the long-term consequences of such relatively common LBW concommitants as brain hemorrhages, respiratory distress syndrome, or patent ductus arteriosus. It remains to be seen if the severity of hemorrhage affects such abilities as language processing once the children are latency age.

Suggestions for the design of future research. Several of the suggestions that follow are easily predicted from the questions just mentioned which still need to be addressed:

1. Researchers need to begin looking at longer longitudinal studies, those which will follow a cohort of LBW children well into grade school at the minimum. It is easy to understand why this is not a common practice. The cost is tremendous, and there is usually significant subject mortality which can confound the most carefully designed study. However, in order to answer questions regarding educational and functional needs of the next generation,

such studies are essential.

2. Researchers need to be evaluating more subtle difficulties. It is relatively easy to classify children as "normal," "suspect/borderline" or "abnormal," but such distinctions are not helpful when planning a child's individualized educational program. Specific areas of potential difficulty need to be assessed, including: attention problems, behavioral disorders, learning difficulties, and language deficits.

3. When evaluating these areas of potential difficulty, researchers should be cautious to select instruments which have good psychometric properties and are widely used so that results can be understood by the most number of people and can be considered reliable and valid.

4. When the data are collected on the school-age cohort, it is vital to include prenatal and perinatal details so as to learn how these affect later abilities.

5. One of the more surprising results was the fact that test norms were not comparable to matched control groups. This indicates that in order to have an accurate comparison from which to determine deficits, it is essential to use a control group. To make the comparison viable, the control group should be matched on such variables as SES, parental education, maternal age, number of siblings, amount of early intervention, and quality of school the child is attending.

6. In addition to comparing LBW children with full term controls, it would be useful to make distinctions between certain groups of LBW children. Of concern to this study was how IVH affected outcome. To address this question among school-age children the research design should include a full term control group and an LBW group that did not experience brain hemorrhage. When assessing any of the perinatal complications, the use of two control groups is nearly always necessary.

7. In most cases the researchers indicated that the people performing the assessments were unaware of the child's birthweight status and/or the hypotheses being tested. However, a significant number of studies did not address this consideration. In research of this type, experimenter blindness is one of the most potent confounds and should be acknowledged in all documentation of studies.

8. Due to the significant research problems caused by subject mortality in longitudinal studies, every effort should be made to keep subjects enrolled in the project. Subject characteristics of those who drop out should be done so as to assess how this group may differ from those who remain in the study.

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APPENDIX

APPENDIX A

MASTER LIST OF REFERENCES

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APPENDIX

APPENDIX B

STUDIES WHICH MET INCLUSION CRITERIA

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APPENDIX

APPENDIX C

STUDIES WHICH DID NOT MEET INCLUSION CRITERIA

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APPENDIX

APPENDIX D

CODING FORM AND DICTIONARY

AUTHORS:_____

TITLE:_____

JOURNAL:_____

YEAR:_____ VOL:_____ PAGES:_____

CASE1 1-3	___ ___ ___	OUTAB 37-39	___ ___ ___	BDESCR 12-13	___ ___
CARD1	1	ADESCR 40-41	___ ___	BSIZE 14-16	___ ___ ___
STUDY 5-7	___ ___ ___	ASIZE 42-44	___ ___ ___	BGEST 17-19	___ ___.___
PUB 8-9	___ ___	AGEST 45-47	___ ___.___	BWEIG20-23	___ ___ ___ ___
COMP# 10-11	___ ___	AWEIG48-51	___ ___ ___ ___	B1MIN 24-25	___.___
SITE 12	___	A1MIN 52-53	___.___	B5MIN 26-27	___.___
INOUT 13	___	A5MIN 54-55	___.___	BIVH 28-29	___ ___
AGE 14-16	___ ___ ___	AIVH 56-57	___ ___	BBPD 30-31	___ ___
AGEADJ 17	___	ABPD 58-59	___ ___	BPDA 32-33	___ ___
BEGIN 18-19	___ ___	APDA 60-61	___ ___	BRDS 34-35	___ ___
END 20-21	___ ___	ARDS 62-63	___ ___	BTHOR 36-37	___ ___
TYPEDATA 22	___	ATHOR 64-65	___ ___	BAPNEA 38-39	___ ___
EXPBIAS 23	___	AAPNEA 66-67	___ ___	BTHROM 40-41	___ ___
MATUR 24	___	ATHROM 68-69	___ ___	BPNEUM 42-43	___ ___
HISTORY 25	___	APNEUM 70-71	___ ___	BACID 44-45	___ ___
TESTING 26	___	AACID 72-73	___ ___	BSEIZ 46-47	___ ___
INSTRU 27	___	ASEIZ 74-75	___ ___	BHYDRO 48-49	___ ___
REGRESS 28	___	AHYDRO 76-77	___ ___	BSEP 50-51	___ ___
SELECT 29	___	ASEP 78-79	___ ___	BGENMED 52-53	___ ___
MORTAL 30	___	CASE2 1-3	___ ___ ___	BSES 54-55	___ ___
QUALITY 31	___	CARD2 4	2		
DESCR 32	___	STUDY 5-7	___ ___ ___		
ESAB 33-36	___ ___.___ ___	AGENMED 8-9	___ ___		
		ASES 10-11	___ ___		

5. SITE OF STUDY
1=AUSTRALIA/NEW ZEALAND
2=CANADA
3=ENGLAND
4=EUROPE
5=USA
6=OTHER
8=NOT SPECIFIED

6. INBORN VS. OUTBORN
1=INBORN
2=BOTH INBORN AND OUTBORN
3=OUTBORN
8=NOT SPECIFIED

8. AGE ADJUSTMENT
1=USED
2=MIXED
3=NOT USED
8=NOT SPECIFIED

11. LENGTH AND TYPE OF DESIGN
1=LONGITUDINAL, PROSPECTIVE
2=LONGITUDINAL, RETROSPECTIVE
3=SINGLE TIME, PROSPECTIVE
4=SINGLE TIME, RETROSPECTIVE
8=CAN'T TELL

12-19. INTERNAL VALIDITY THREATS
0=NOT PLAUSIBLE THREAT
1=POTENTIAL MINOR THREAT
2=PLAUSIBLE ALTERNATIVE TO ACCOUNT FOR RESULTS
3=MAJOR THREAT, COULD EXPLAIN MOST OF OBSERVED RESULTS
8=NO WAY TO TELL

20. QULAITY OF STUDY
1= EXCELLENT
5= VERY POOR

21. ADEQUACY OF SUBJECT DESCRIPTION
1= COMPLETE
2= SOMEWHAT SKETCHY
3= INADEQUATE

34. DESCRIPTOR OF GROUP
PRETERMS, AGA
1=BW <700 GRAMS
2=BW <750 GRAMS
3=BW <1000 GRAMS
4=BW <1000, >750 GRAMS
5=BW <1250 GRAMS
6=BW <1250, >750 GRAMS
7=BW <1250, >1000 GRAMS
8=BW <1500 GRAMS
9=BW <1500, >750 GRAMS
10=BW <1500, >1000 GRAMS
11=BW <1500, >1250 GRAMS
12=BW <2000 GRAMS
13=BW <2500 GRAMS

PRETERMS, SGA
21=BW <700 GRAMS
22=BW <750 GRAMS
23=BW <1000 GRAMS
24=BW <1000, >750 GRAMS
25=BW <1250 GRAMS
26=BW <1250, >750 GRAMS
27=BW <1250, >1000 GRAMS
28=BW <1500 GRAMS
29=BW <1500, >750 GRAMS
30=BW <1500, >1000 GRAMS
31=BW <1500, >1250 GRAMS
32=BW <2000 GRAMS
33=BW <2500 GRAMS
34=BW <3000 GRAMS
99=FULLTERM BABIES

40. PRESENCE OF IVH
01=IVH EXCLUDED
02=IVH GRADE 1
03=GRADES 1 AND 2 COMBINED
04=IVH GRADE 2
05=NO GRADE SPECIFIED OR ALL GRADES TOGETHER
06=GRADES 2 AND 3 COMBINED
07=IVH GRADE 3
08=GRADES 3 AND 4 COMBINED
09=IVH GRADE 4
88=NOT MENTIONED, UNKNOWN

CODING KEY FOR ASSESSMENTS

MENTAL

01 Batelle -General
02 Cognitive
03 Bayley M D I
04 Blind Learning Aptitude
05 Columbia Mental Mat
06 Denver Develop Screen
07 DTLA General, Composite
08 Cognitive
09 Geselle
10 Griffith
11 Hiskey-Nebrask Learning
12 Leiter
13 K-ABC General Intell
14 Nonverbal Scale
15 McCarthy General
16 Cognitive
17 Memory
18 Quantitative
19 Merrill Palmer Scale
20 Pictoral Test of Intelligence
21 Raven's Progressive Matrices
22 Slossen
23 Stanford-Binet General
24 Verbal
25 Abstract
26 Quantitative
27 Memory
28 WAIS Full Scale
29 Verbal
30 Performance
31 WISC Full Scale
32 Verbal
33 Performance
34 WPPSI Full Scale
35 Verbal
36 Performance
37 Woodcock Johnson Cognitive
38 Misc, Combined Intelligence

ACADEMIC

39 Basic Achievement Skills Indiv
40 Reading
41 Spelling
42 Math
43 Writing
44 Boehm Test of Basic Concepts
45 Bracken Basic Concepts
46 ITPA
47 K-ABC Achievement Scale
48 KTEA Overall
49 Reading
50 Spelling
51 KTEA Math
52 PIAT Overall
53 Reading
54 Spelling
55 Math
56 Sequential Assmnt of Math
57 Woodcock-Johnson
58 Reading
59 Written Language
60 Math
61 Knowledge
62 WRAT Overall
63 Reading
64 Spelling
65 Math
66 Misc, Combined Measures

LANGUAGE

67 Auditory Discrim Test (ADT)
68 Bankson Lang
69 Batelle Communication
70 DTLA Linguistic
71 Edinburgh Artic Test
72 Expressive One Word Pic
73 Goldman-Fristoe Woodcock Aud
74 Lindamood Auditory Concept Test
75 Kahn-Lewis Phonolo Test
76 McCarthy Verbal Scale
77 PPVT
78 Phonological Assessmnt
79 Preschool Lang Scale
80 REEL
81 Reynell Verbal Comp
82 Express Lang
83 SICD
84 Test Auditory Compr

85 TELD
86 Test of Lang Dev (TOLD)
87 Verbal Lang Dev Scale (VLDS)
92 Misc, combined measures

VISUAL MOTOR, FINE MOTOR
93 Bender-Gestalt, Koppitz
94 Bender-Gestalt, SOMPA
95 VMI
96 McCarthy Perceptual
102 Misc, Combined

MOTOR
103 Batelle Motor
104 Bayley Psychomotor
105 Bruininks-Oseretsky
106 DTLA Motor Domain
107 McCarthy Motor Scale
113 Misc, Combined

BEHAVIOR
114 AAMD Adaptive Beh Scale (ABS)
115 AAMD Adapt. Beh Scale, School
116 Achenbach Child Beh Chkl (CBC)
117 Adaptive Behavior Inv
118 Balthazar Scales Adptve Beh
119 Batelle Adaptive
120 Burks Behav Scale
121 Conners Parent
122 Teacher
123 Revised Beh Problem Checklist
124 Scales of Indep Beh
125 TMR School Competency
126 Vineland Adaptive Beh
127 Wisconsin Beh Rating
134 Misc Combined

PERSONALITY/TEMPERAMENT
135 Batelle Personal/Soc
136 Child Depression Inventory
137 Piers-Harris
138 Primary Self Concept
150 Misc, Combined

ASPECTS OF TEMPERAMENT
151 Activity
152 Adaptibility
153 Approach/withdrawal
154 Attention/Distract
155 DTLA Attention Domain
156 Intensity
157 Mood
158 Persistence
159 Rhythmicity
160 Threshold

Definitions of Validity Threats

History: Events, other than the experimental treatment, occurring between pre-test and post-test and thus providing alternate explanations of effects.

Maturation: Processes within the respondents or observed social units producing changes as a function of the passage of time per se, such as growth fatigue, secular trends, etc.

Testing: The effect of taking a test upon the scores of a second testing. The effect of publication of a social indicator upon subsequent readings of that indicator. The effect of repeated testings on a given group.

Instrumentation: Changes in the calibration of a measuring instrument or changes in the observers or scorers used producing changes in the obtained measurements

Regression to the Mean: Pseudo-shifts occurring when subjects or treatment units have been selected upon the basis of extreme scores.

Selection: Biases resulting from differential recruitment of comparison groups, producing different mean levels on the measure of effect.

Subject Mortality: The differential loss of respondents from comparison groups.

APPENDIX

APPENDIX E

EQUATIONS AND TEST NORMS USED FOR EFFECT SIZE COMPUTATION

1. Direct Calculation

$$\frac{Y_E - Y_C}{S_C}$$

Where:
Y_E is the score for the experimental group
Y_C is the score for the control group
S_C is the standard deviation for the control group

2. From t Test Designs

$$ES = t \sqrt{\frac{1}{n_E} + \frac{1}{n_C}}$$

Where:
n_E is the number of experimental subjects
n_C is the number of control subjects

This assumes $S_E = S_C$.

3. One-way ANOVA Designs, with only two treatment groups

$$ES = 2 \sqrt{\frac{F}{n_E + n_C}}$$

This assumes $S_E = S_C$.

Means and Standard Deviations for Major Assessments

	GENERAL		SUBTESTS	
	MEAN	SD	MEAN	SD
COGNITIVE/DEVELOPMENTAL				
Batelle	100	15		
Bayley	100	16		
Blind Learning Aptitude	100	15		
Columbia Mental Maturity	100	16		
Denver Developmental Screen	No scores possible			
Detroit Test Learning Apt	100	15		
Goodenough DAP	100	15		
Griffith	100	12		
Hiskey-Nebrask Learning	100	16		
Leiter	100	16		
K-ABC	100	15	10	3
McCarthy	100	16	50	10
Merrill Palmer Extended	Percentile Ranks			
Pictoral Test of Intelligence	100	16		
Raven's Progressive Matrices	Based on percentiles			
Slossen	100	16		
Stanford-Binet	100	16		
WISC, WAIS, WPPSI	100	15	10	3
ACADEMIC				
Basic Achievement Skills	100	15		
Boehm Test of Basic Concepts	50	10	or Percentiles	
Bracken Basic Concept Scale School Readiness Composite	100	15		
ITPA	100	varies	36	6
KTEA	100	15		
PIAT	100	15		
Sequential Assmnt of Math	100	15	10	3
Woodcock-Johnson	100	15	50	10
WRAT	100	15	10	3
LANGUAGE				
Auditory Discrim Test (ADT)	50	15		
Goldman-Fristoe Aud Disc	50	10		
Lindamood Auditory Concept	Percentile Ranks			
PPVT	100	15		
Test of Auditory Compre	100	15		
MOTOR, VISUAL MOTOR				
Bender-Gestalt, Koppitz	100	15		
Bender-Gestalt, SOMPA	50	15		
Bruininks-Oseretsky	50	10	15	5
VMI	10	3		

	GENERAL QUOTIENT		SUBTESTS	
	MEAN	SD	MEAN	SD
BEHAVIOR				
AAMD Adaptive Behavior Scale	Percentile Rank			
AAMD School Edition	10	3		
Achenbach Child Beh (CBC)	50	10		
Adaptive Behavior Inv	50	10		
Balthazar Scales Adaptive Beh	Percentile Rank			
Conners Parent, Teacher	50	10		
Revised Beh Problem Checklist	50	10		
Scales of Independent Beh	100	15		
TMR School Competency Scales	Percentile Rank			
Vineland Adaptive Behavior	100	15		
Wisconsin Behavior Rating	Percentile Rank			

APPENDIX

APPENDIX F

BREAKDOWNS OF AGE AT ASSESSMENT BY GRADE OF HEMORRHAGE

Table F-1

Age at Which Cognitive/Developmental Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
	N	14	1	5	1	17		2	4		44
LT 9	Row Pct	31.8%	2.3%	11.4%	2.3%	38.6%		4.5%	9.1%		14.2%
Months	Col Pct	25.5%	10.0%	22.7%	8.3%	10.6%		11.1%	22.2%		
	N	14	2	6	3	24		3	6	1	59
9 to 12	Row Pct	23.7%	3.4%	10.2%	5.1%	40.7%		5.1%	10.2%	1.7%	19.1%
Months	Col Pct	25.5%	20.0%	27.3%	25.0%	15.0%		16.7%	33.3%	8.3%	
	N	11	2	3	2	9	2	4	2	3	38
15 to 21	Row Pct	28.9%	5.3%	7.9%	5.3%	23.7%	5.3%	10.5%	5.3%	7.9%	12.3%
Months	Col Pct	20.0%	20.0%	13.6%	16.7%	5.6%	100.0%	22.2%	11.1%	25.0%	
	N	8	4	3	4	32		5	2	4	62
22 to 24	Row Pct	12.9%	6.5%	4.8%	6.5%	51.6%		8.1%	3.2%	6.5%	20.1%
Months	Col Pct	14.5%	40.0%	13.6%	33.3%	20.0%		27.8%	11.1%	33.3%	
	N	5		2		9			3		19
30 to 38	Row Pct	26.3%		10.5%		47.4%			15.8%		6.1%
Months	Col Pct	9.1%		9.1%		5.6%			16.7%		
	N	3	1	3	2	21		4	1	4	39
42 to 63	Row Pct	7.7%	2.6%	7.7%	5.1%	53.8%		10.3%	2.6%	10.3%	12.6%
Months	Col Pct	5.5%	10.0%	13.6%	16.7%	13.1%		22.2%	5.6%	33.3%	
	N					17					17
6 to 8	Row Pct					100.0%					5.5%
Years	Col Pct					10.6%					
	N					31					31
8 to 11	Row Pct					100.0%					10.0%
Years	Col Pct					19.4%					
Total	N	55	10	22	12	160	2	18	18	12	309
	Col Pct	17.8%	3.2%	7.1%	3.9%	51.8%	0.6%	5.8%	5.8%	3.9%	100.0%

Table F-2

Age at Which Academic Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N Row Pct Col Pct										
9 to 12 Months	N Row Pct Col Pct										
15 to 21 Months	N Row Pct Col Pct										
22 to 24 Months	N Row Pct Col Pct										
30 to 38 Months	N Row Pct Col Pct										
42 to 63 Months	N Row Pct Col Pct										
6 to 8 Years	N Row Pct Col Pct										
8 to 11 Years	N Row Pct Col Pct					9 100.0% 100.0%					9 100.0%
Total	N Col Pct					9 100.0%					9 100.0%

Table F-3

Age at Which Speech/Language Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N	1									1
	Row Pct	100.0%									1.8%
	Col Pct	7.1%									
9 to 12 Months	N					4					4
	Row Pct					100.0%					7.1%
	Col Pct					13.3%					
15 to 21 Months	N	7				3					10
	Row Pct	70.0%				30.0%					17.9%
	Col Pct	50.0%				10.0%					
22 to 24 Months	N	2		1		11			1		15
	Row Pct	13.3%		6.7%		73.3%			6.7%		26.8%
	Col Pct	14.3%		20.0%		36.7%			20.0%		
30 to 38 Months	N	3		3		8			4		18
	Row Pct	16.7%		16.7%		44.4%			22.2%		32.1%
	Col Pct	21.4%		60.0%		26.7%			80.0%		
42 to 63 Months	N	1		1		1		1		1	5
	Row Pct	20.0%		20.0%		20.0%		20.0%		20.0%	8.9%
	Col Pct	7.1%		3.3%		3.3%		100.0%		100.0%	
6 to 8 Years	N										
	Row Pct										
	Col Pct										
8 to 11 Years	N					3					3
	Row Pct					100.0%					5.4%
	Col Pct					10.0%					
Total	N	14		5		30		1	5	1	56
	Col Pct	25.0%		8.9%		53.6%		1.8%	8.9%	1.8%	100.0%

Table F-4

Age at Which Fine Motor Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N Row Pct Col Pct										
9 to 12 Months	N Row Pct Col Pct					4 100.0% 25.0%					4 15.4%
15 to 21 Months	N Row Pct Col Pct	2 100.0% 40.0%									2 7.7%
22 to 24 Months	N Row Pct Col Pct	1 33.3% 20.0%				2 66.7% 12.5%					3 11.5%
30 to 38 Months	N Row Pct Col Pct	1 25.0% 20.0%		1 25.0% 50.0%		1 25.0% 6.3%			1 25.0% 100.0%		4 15.4%
42 to 63 Months	N Row Pct Col Pct	1 16.7% 20.0%		1 16.7% 50.0%		2 33.3% 12.5%		1 16.7% 100.0%		1 16.7% 100.0%	6 23.1%
6 to 8 Years	N Row Pct Col Pct					3 100.0% 18.5%					3 11.5%
8 to 11 Years	N Row Pct Col Pct					4 100.0% 25.0%					4 15.4%
Total	N Col Pct	5 19.8%		2 5.8%		16 61.5%		1 3.8%	1 3.8%	1 3.8%	26 100.0%

Table F-5

Age at Which Gross Motor Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N	7	1	3	1	12		2	2		28
	Row Pct	25.0%	3.6%	10.7%	3.6%	42.9%		7.1%	7.1%		22.2%
	Col Pct	22.6%	16.7%	30.0%	14.3%	25.5%		18.2%	28.6%		
9 to 12 Months	N	7	2	1	3	11		3	1	1	29
	Row Pct	24.1%	6.9%	3.4%	10.3%	37.9%		10.3%	3.4%	3.4%	23.0%
	Col Pct	22.6%	33.3%	10.0%	42.9%	23.4%		27.3%	14.3%	20.0%	
15 to 21 Months	N	9	1	2	1	7	2	2	2	1	27
	Row Pct	33.3%	3.7%	7.4%	3.7%	25.9%	7.4%	7.4%	7.4%	3.7%	21.4%
	Col Pct	29.0%	16.7%	20.0%	14.3%	14.9%	100.0%	18.2%	28.6%	20.0%	
22 to 24 Months	N	7	2	3	2	15		4	1	3	37
	Row Pct	18.9%	5.4%	8.1%	5.4%	40.5%		10.8%	2.7%	8.1%	29.4%
	Col Pct	22.6%	33.3%	30.0%	28.6%	31.9%		36.4%	14.3%	60.0%	
30 to 38 Months	N	1		1					1		3
	Row Pct	33.3%		33.3%					33.3%		2.4%
	Col Pct	3.2%		10.0%					14.3%		
42 to 63 Months	N										
	Row Pct										
	Col Pct										
6 to 8 Years	N					2					2
	Row Pct					100.0%					1.6%
	Col Pct					4.3%					
8 to 11 Years	N										
	Row Pct										
	Col Pct										
Total	N	31	6	10	7	47	2	11	7	5	126
	Col Pct	24.6%	4.8%	7.9%	5.6%	37.3%	1.6%	8.7%	5.6%	4.0%	100.0%

Table F-6

Age at Which Personality Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N					1					1
	Row Pct					100.0%					1.9%
	Col Pct					2.9%					
9 to 12 Months	N					12					12
	Row Pct					100.0%					23.1%
	Col Pct					34.3%					
15 to 21 Months	N	6				2					8
	Row Pct	75.0%				25.0%					15.4%
	Col Pct	54.5%				5.7%					
22 to 24 Months	N	3				6					9
	Row Pct	33.3%				66.7%					17.3%
	Col Pct	27.3%				17.1%					
30 to 38 Months	N	1		1		1			2		5
	Row Pct	20.0%		20.0%		20.0%			40.0%		9.6%
	Col Pct	9.1%		50.0%		2.9%			100.0%		
42 to 63 Months	N	1		1		1		1		1	5
	Row Pct	20.0%		20.0%		20.0%		20.0%		20.0%	9.6%
	Col Pct	9.1%		50.0%		2.9%		100.0%		100.0%	
6 to 8 Years	N					4					8
	Row Pct					100.0%					15.4%
	Col Pct					22.9%					
8 to 11 Years	N					4					4
	Row Pct					100.0%					7.7%
	Col Pct					11.4					
Total	N	11		2		35		1	2	1	52
	Col Pct	21.2%		3.8%		67.3%		1.9%	3.8%	1.9%	100.0%

Table F-7

Age at Which Temperament Testing Was Administered by IVH Grade

		IVH Excluded	Grade I	Grades I & II	Grade II	All Grades	Grades II & III	Grade III	Grades III & IV	Grade IV	Row Total
LT 9 Months	N	17		6		9			6		38
	Row Pct	44.7%		15.8%		23.7%			15.8%		74.5%
	Col Pct	100.0%		100.0%		40.9			100.0%		
9 to 12 Months	N					9					9
	Row Pct					100.0%					17.6%
	Col Pct					40.9%					
15 to 21 Months	N										
	Row Pct										
	Col Pct										
22 to 24 Months	N										
	Row Pct										
	Col Pct										
30 to 38 Months	N										
	Row Pct										
	Col Pct										
42 to 63 Months	N										
	Row Pct										
	Col Pct										
6 to 8 Years	N					4					4
	Row Pct					100.0%					7.8%
	Col Pct					18.2%					
8 to 11 Years	N										
	Row Pct										
	Col Pct										
Total	N	17		6		22			6		51
	Col Pct	33.3%		11.8%		43.1%			11.8%		100.0%

APPENDIX

APPENDIX G

Table G-1

Mean Effect Size of Personality and Temperament Differences

		IVH Excluded	Grades I & II	All Grades	Grades III & IV	Total Sample
LT 9 Months	Mean	.09	1.09	-0.36	.76	.23
	Std Dev	.52	.55	.40	.37	.68
	N	17	6	10	6	39
9 to 12 Months	Mean			.05		.05
	Std Dev			.96		.96
	N			21		21
15 to 21 Months	Mean	2.23		.75		1.86
	Std Dev	1.45		1.08		1.46
	N	6		2		8
22 to 24 Months	Mean	.08		.45		.32
	Std Dev	.05		.48		.43
	N	3		6		9
30 to 38 Months	Mean	.96	.97	1.78	1.59	1.38
	Std Dev	.00	.00	.00	.21	.40
	N	1	1	1	2	5
42 to 63 Months	Mean	.50	.30	.44	.90	.61
	Std Dev	.00	.00	.00	.14	.29
	N	1	1	1	2	5
6 to 8 Years	Mean			.58		.58
	Std Dev			.36		.36
	N			12		12
8 to 11 Years	Mean			.96		.96
	Std Dev			.11		.11
	N			4		4
Total	Mean	.59	.98	.26	.96	.48
	N	28	8	57	10	103

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