THE INFLUENCE OF MULTIPLE RISK FACTORS ON VERY LOW BIRTH WEIGHT INFANTS

Barbara D. Schraeder

"Vulnerable" and "at risk" are words used to describe very low birth weight infants (VLBW <1500 grams). These infants are assigned a high risk status because their intrinsic vulnerability is coupled with factors that are known to influence outcome negatively. The spectrum of risk varies, however, depending on a child's total milieu and on the ability to change or to resist change in response to that milieu (Alyward & Kenny, 1979). For instance, extreme prematurity, prolonged hospitalization and exposure to iatrogenesis may place a child at great risk for cognitive deficits. Discharge from the hospital into the care of interested, loving parents may minimize that risk. Similarly, a healthy, physiologically intact, premature infant may experience deficits if reared in an indifferent environment. The dynamic relationship between the child and his or her environment determines risk status and outcome is the result of the child and the environment regularly restructuring one another (Sameroff & Chandler, 1975). Change may occur as the child matures, with biological and medical factors becoming less important and environmental and social factors becoming more important. This restructuring of the milieu can amplify or minimize the child's degree of risk.

The purpose of this longitudinal study is to describe the developmental progress of children who were of VLBW. A comprehensive holistic model is used to identify medical, biological and environmental factors that influence risk and outcome, and to track their influence over time.

These well-documented factors that influence outcome are: intraventricular hemorrhage status (Williamson, Desmond, Wilson, Andrew & Garcia-Pratz, 1982); the number of days supported by mechanical ventilation (Ruiz, LeFever, Hakanson, Clark & Williams, 1981); birth weight (Kopp, 1983); the length of time in the intensive care nursery (Lawson, Daum &

Barbara D. Schraeder, R.N., Ph.D. is Associate Professor in the Department of Nursing at Rutgers University, in Camden, N.J.

Turkowitz, 1977); and environmental process variables (Sigman, Cohen, Beckwith & Parmalee, 1981). Environmental process variables are observations of specific transactions, objects and events occurring in the home. They provide more specific information than an environmental variable such as socio-economic status and can provide direction for intervention strategies (Casey & Bradley, 1982).

Data from the first year of the study support the assertion that developmental progress in VLBW infants is sensitive to environmental influences and that infants may "self-right" in optimal environments (Schraeder, 1986). Questions left unanswered concern the maintenance of this positive developmental trajectory over time. Also to be considered is the possible reemergence of perinatal risk factors as important variables affecting development. After the first eighteen months of life, development is characterized by the increasing ability to conceptualize and symbolize. These cognitive skills may be more sensitive to the deleterious effects of biological immaturity and perinatal adversity than the skills of the earlier sensori-motor period.

The following questions were posed during the second year of the study.

1. How much of the variance in the developmental progress of 24-month-old corrected gestational age (CGA) toddlers who were of VLBW is explained by the medical, biological and environmental variables in combination?
2. What is the relative importance of the medical, biological and environmental variables in explaining developmental progress at 24 months CGA?
3. What is the effect of time on the developmental progress of the toddler who was very low birth weight during the first two years of life?
4. What is the effect of environmental process variables on the developmental progress of VLBW infants during the first two years of life?

Methods

Subjects and procedures

Thirty-eight of the 41 families who originally entered the study were located and assessed during the second year. Measures to prevent attrition from Year One to Year Two included telephone contact and the provision of a stamped post-card for the families to inform the researcher of a planned move or change in telephone number. Despite these measures one family moved and left no forwarding address. Two families continued in the study but were visiting relatives in another city and did not participate in the second year of the study. The three children who were not assessed during Year Two were developmentally appropriate at Year One. The first year's proce-

dures have been described in an earlier report (Schraeder, 1986). All of the subjects were appropriate for gestational age and free from congenital anomalies. Table 1 describes the characteristics of the study sample.

Data concerning the variables, days on mechanical ventilation (DMV); number of days in the intensive care nursery (ICN), intraventricular hemorrhage status (IVH) and birth weight (BW) had been obtained from the children's original medical record (Schraeder, 1986). The birth weights ranged from 780 grams to 1500 grams (X=1203 grams; SD=190.82). The mean length of stay in the ICN was 54.8 days (SD=30.83; range=11 to 197). Days of support on mechanical ventilation ranged from zero to 125 (X=9.04; SD=20.73).

Table 1

Characteristic of the Second Year Sample (N=38)

Characteristic		Frequencies
Intraventricular Hemorrhage Status		
Negative Scans		25
Grade I		2
Grade II		4
Grade III		0
Grade IV		1
No Scan		6
Gender		
Males		17
Females		21
Social Class Status* - %		
I	Parent unemployed, on welfare, deceased or missing	29
II	Unskilled or semi skilled worker	26
III	Skilled worker or clerical	22
IV	Medium Business or Technical	18
V	Major Business or Professional	5

* From Duncan Socioeconomic Index (Reiss, Duncan, Holt and North, 1961)

During the second year of the study, each family and child was assessed when the child reached the corrected gestational age of 24 months. The mean CGA was 24.4 months (range=24 to 27 months). The mean chronological age was 26.8 months (range=25.5 to 30 months). All visits took place in the families' homes and the procedures followed for the visits were identical to the first year of the study (Schraeder, 1986). Consent to participate in the study was obtained during an initial phone call to all the families before any home visits were scheduled. Written consent was obtained from each family at the beginning of the home visits during Year One and Year Two.

Instruments

Home Observation for Measurement of the Environment (HOME) Inventory (birth to three years). The HOME was used to assess environmental process variables thought to be important to the child's developmental progress. The instrument examines aspects of the childrearing environment from birth to three years that support social, emotional and cognitive development. Six areas are assessed: emotional and verbal responsiveness of mothers, avoidance of restriction and punishment, organization of the physical and the temporal environment, provision of the appropriate play materials, maternal involvement with the child and opportunities for variety in daily stimulation (Caldwell, 1978).

The HOME yields a total score and six subscale scores. The established interrater reliability is .90 (Elardo, Bradley & Caldwell, 1977). Internal consistency coefficients range from .44 to .89 for the subscales and .89 for the total scale. The validity of the HOME has been extensively established and described (Elardo & Bradley, 1981). Interrater reliability was established for this study using procedures described in the HOME manual (Caldwell, 1978). An interrater reliability score of .90 was obtained within the first two visits. The HOME Total scores of the sample ranged from 11 to 45. The mean score was 36.47 and the SD was 7.87.

Minnesota Child Development Inventory (MCDI). This 320-item instrument assesses children's development from the newborn period to six years of age using mothers' observations, (Ireton & Thwing, 1974). The MCDI yields a profile of the child's development based on eight scales: general development, gross motor, fine motor, expressive language, comprehension-conceptual, situational comprehension, self-help and personal-social. The general development scale is composed of the most discriminating items from the other seven scales. For a particular child, the score is the number of items answered "yes" by the mother.

A child's development is appropriate if the score is at or above the mean score for children 20 percent younger than the child. Development is suspect

if the score falls in the range for children 21 percent to 30 percent younger. It is inappropriate for age if it falls below the mean score of children 30 percent younger than the child. Of the normative sample, fewer than three percent fell within the borderline range and one percent fell below the 30 percent cut-off. The inventory was validated on a sample of 796 children from 6 months to 6 1/2 years of age. The norms are for age and sex. Internal reliability coefficients for the eight scales range from .43 to .93 (Ireton & Thwing, 1974). The general development scale for 24 months has an internal reliability coefficient of .93. The inventory, although standardized on full-term children, has been used to study the development of low birth weight infants and correlates well with objective cognitive tests (r .48 to .66; $p<.05$) (Byrne, Backman & Smith, 1986; Eisect, Spector, Shankaron, Fargenbaum, & Szygo, 1980). The tool has also been used to study disadvantaged groups and was found to identify developmental strengths and weaknesses accurately (Ullman & Kausch, 1979).

For this study, in addition to identifying children who were developmentally appropriate, suspect and inappropriate, a standardized developmental score was assigned to each child. This score was constructed by converting the age-equivalent score on the General Development Scale to a developmental quotient (Mental age/Chronological age x 100). This method, reported by Byrne, Backman & Smith (1986) and recommended by the developer of the tool, facilitated the comparison of scores from the first to the second year of the study (H. Ireton, personal communication, November, 1983).

Denver Developmental Screening Test (DDST). The DDST is a general scale that measures personal and social skills, language and gross and fine motor abilities. It is designed to detect developmental delays during infancy and the preschool years. Risk is determined in one of two ways: a child has two or more failures in two or more sections; or, a child has two or more failures in one section, plus one or more sections with one failure and in that same section no passes through the age line (Frankenburg & Dodd, 1967).

The DDST was used to give the researcher an opportunity to assess the child directly. It was not used as a measure of the dependent variable. Its results confirmed the accuracy of the MCDI in categorizing developmental risk status. There was 100% congruence in the assessment of appropriate, suspect and inappropriate development between the MCDI and the DDST.

Results

After scatter plots were examined to ensure that the assumption of linearity was not violated, stepwise multiple regression analysis was used to analyze the data on the medical, biological and environmental factors. It is recog-

nized that the use, in this study of multiple regression analysis, with a relatively small sample violates the recommendation that there be ten to 30 subjects per variable (Pedhazur, 1982). This violation is justified for the following reasons: surviving VLBW infants constitute a small subset of infants and it is difficult to gather large samples of them; and, model building to explain outcome for VLBW infants is in its very early stages. At this time, the value of using multivariate statistics to test new ideas and identify new approaches may compensate for the lack of precision in analysis. The results should be interpreted, however, with the caveat that multivariate analysis with small sample sizes tends to overestimate the variance accounted for in the dependent variable. The R2 adjusted is reported in Tables 2 and 4 to compensate for measurement error (Prescott, 1987). The stepwise multiple regression analysis revealed that 32 percent of the variance in MCDI scores was accounted for by the combination of environmental, biological and medical factors (Table 2). A comparison of standardized beta weights revealed that the total HOME (B .57) was the most important variable. The next most important variable was number of days in the intensive care nursery (B .25) (Table 3).

Table 2

Multiple Regression Analysis with Predictor Variables and Minnesota Child Development Inventory- 24 months (N=38)

Order Variable Entered	Multiple R	R2	Adjusted R2	R2 change	Simple R	Overall F
HOME TOTAL	.42	.18	.15	.18	.42	7.317*
ICU	.55	.31	.26	.13	-.20	7.277*
IVH	.56	.31	-.-	.05	-.07	-.-
BWT	.56	.31	-.-	.05	.07	-.-
DVM	.57	.32	.21	.02	-.23	2.873*

* p <.001
N=38

HOME TOTAL HOME: Observation for Measurement of the Environment
ICU: Number of Days in Level III Nursery
IVH: Intraventricular Hemorrhage Status
BWT: Birthweight
DMV: Days on Mechanical Ventilation

Table 3

Standardized Beta Weights and R2 Changes for Independent Variables and 24 Month Minnesota Child Development Inventory Scores (N=38)

Variable	Beta Weight	R2 Change
HOME TOTAL	.57	.18
ICU	.25	.13
BWT	.14	.05
DMV	.09	.02
IVH	.02	.05

HOME TOTAL HOME: Observation for Measurement of the Environment
ICU: Number of Days in Level III Nursery
BWT: Birthweight
DMV: Days on Mechanical Ventilation
IVH: Intraventricular Hemorrhage Status

In order to determine which of the HOME subscales were important in predicting outcome, a second stepwise multiple regression analysis was run. Five HOME subscales in combination accounted for 47% of the variance in MCDI score. (Table 4) Provision of appropriate play materials (B=.69) was the most important environmental variable with maternal involvement with the child the second most important (B=.40) (Table 5).

Analysis of the MCDI scores by category revealed that four children were below the 30 percent cut-off indicative of inappropriate development, six were within the 21 to 30 percent below age range category which indicates questionable developmental delay, and 28 were within the normal range. Twenty- six percent of the sample had suspect or inappropriate development at two years of age. This contrasts with the 18 percent identified at the end of the first year of the study (Table 6). The MCDI scores for twelve and twenty-four months were highly correlated ($r=.85$, $df=36$, $p<.001$). However, the group mean for the thirty-eight subjects at twenty-four months ($M=88.47$, $SD=24.59$) was significantly lower than the mean for the same thirty-eight subjects at twelve months ($M=94.95$, $SD=29.11$; $t=2.61$, $df=37$, $p<.01$). The subjects appear to have lost ground developmentally from Year One to Year Two. To determine the effects of time and the effects of the home environment on the subjects' development, correlation coefficients were computed and a cross-lagged panel analysis was constructed (Huck, Cormier & Bounds, 1974). The correlation coefficient between total HOME

scores at six months and the MCDI scores at twenty-four months indicates a positive and significant relationship. The relationship is larger and significantly different from the cross-lagged relationships with six-month MCDI scores as the antecedent and 24-month HOME scores as the succedent ($Z=3.00$, $p<.001$) (Table 7). This pattern of relationships suggests that the home environment of the child plays a powerful role in the development of very low birth weight children.

Table 4

Multiple Regression Analysis with Environmental Variables and the Minnesota Child Development Inventory - 24 months (N=38)

Order Variable Entered	Multiple R	R2	Adjusted R2	R2 Change	Simple r	Overall F
HOME 4	.58	.34	.32	.34	.58	17.684*
HOME 5	.61	.38	.34	.03	.47	9.967*
HOME 3	.66	.44	.39	.07	.22	8.455*
HOME 6	.69	.47	.41	.03	.20	7.000*
HOME 1	.69	.47	.39	.00	.37	5.420*

*p<.001

HOME 4 Provision of appropriate play materials
HOME 5 Maternal involvement with child
HOME 3 Organization of the physical and temporal environment
HOME 6 Opportunities for variety of stimulation
HOME 1 Emotional and verbal responsivity of the mother

HOME subscale #2 **Avoidance of Restriction and Punishment** omitted from analysis because of lack of correlation (r=.03)

Table 5

Standardized Beta Weights and R2 Changes for HOME Subscales and 24 Month Minnesota Child Development Inventory Scores (N=38)

Variable	Beta Weight	R2 Change
HOME 4	.69	.34
HOME 5	.40	.03
HOME 3	.29	.07
HOME 6	.24	.03
HOME 1	.002	.00

HOME 4 Provision of appropriate play materials
HOME 5 Maternal involvement with child
HOME 3 Organization of the physical and temporal environment
HOME 6 Opportunities for variety of stimulation
HOME 1 Emotional and verbal responsivity of the mother

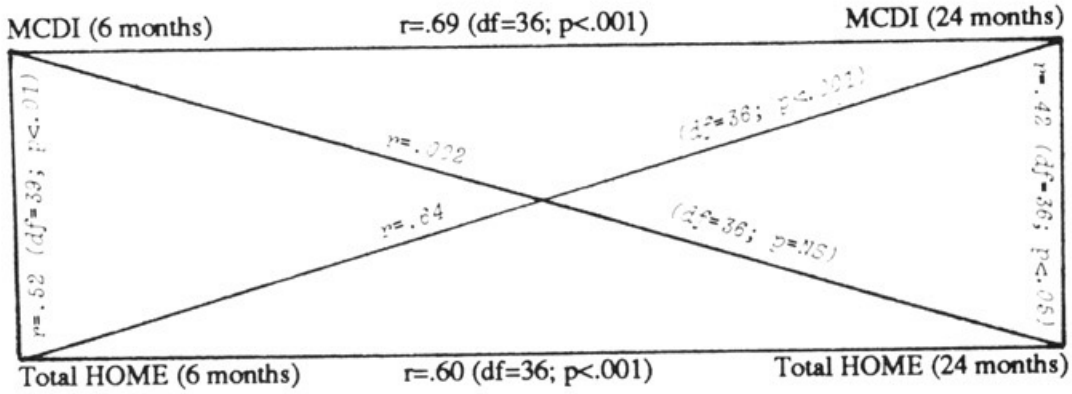
Table 6

Comparison of Very Low Birth Weight Subjects' Minnesota Child Development Inventory Category Scores at 12 and 24 Months (N=38)

Age	Appropriate	Questionable (between 20 & 30%)	Inappropriate (below 30%)
12 mo.	31 (81.68%)	4 (10.5%)	3 (7.9%)
24 mo.	28 (73.7%)	6 (15.8%)	4 (10.9%)

Table 7

Cross-lagged Panel Analysis of HOME Environment and Development from 6 Months to 24 Months



Discussion

The pattern of explained variance in this study supports the theory that developmental progress in at-risk children is improved or diminished by the quality of the environment. The characteristics of the mother's investment in the child: her interest in the child's play; her conscious encouragement of developmental advances; and her verbal attentiveness were important variables. The results concerning the importance of the environment for very low birth weight children are congruent with many studies of both normal and at-risk groups. Elardo, Bradley and Caldwell's (1975) study of 72 normal weight children found that developmental competence at age three was related to maternal involvement and the provision of appropriate play materials during the first three years of life. Bakeman and Brown (1980) also found that the quality of the home environment was predictive of development at three years of age. Studies of preterm infants indicate that the quality of the home environment is even more important for this at-risk group than it is for normal weight children, because the vulnerability associated with preterm birth may be moderated by parental influence (Cohen & Beckwith, 1979; Sigman, et al, 1981).

The pattern of relationships in the cross-lagged panel analysis suggests that the environment is a causative factor rather than merely an associative one. This finding must be tempered by two considerations. The first concerns disagreement among statisticians on the soundness of making causal inferences from cross-lagged correlations. Although this method has been used extensively in longitudinal studies of development, there is a concern that the

determination of causal predominance over-simplifies a complex issue by failing to account for reciprocity and specificity (Rogosa, 1980). The second consideration concerns the theory that parents transfer both genes and environments to their children. Parents, in addition to influencing their children's potential genetically, create environments that support their cognitive abilities. The influence of parental intelligence, either through genetic endowment or environment, may be an unknown "third" variable influencing development (Elardo & Bradley, 1981; Wachs & Mariotto, 1978). Sorting out that issue is beyond the scope of this study.

The increase in inappropriate development and the decrease in mean MCDI scores from Year One to Year Two is consistent with reports in the literature. One study of 61 VLBW children found a similar decline which the researchers attributed to performance disabilities possibly indicative of minimal brain dysfunction (Astbury, Orgill, Bejuk & Yu, 1983). Escalona (1982) found that the developmental decline in her group of VLBW infants was most pronounced in those infants who were in the lowest socioeconomic group. Because so many variables are subsumed under SES, it is difficult to isolate any specific one as the culprit.

One possible explanation for the decline in scores from Year One to Year Two may lie with the nature of intelligence in the two year old and the composition of the test items used to measure it. According to Piagetian theory, the symbolic function that emerges at eighteen to twenty-four months is qualitatively different from intelligence as expressed in the sensori-motor stage. The two-year-old is developing a repertoire of operations, including the use of language and the ability to understand and use simple concepts (McCall, 1979). These skills also emerge in developmental tests. A comparison of MCDI items for one-year-olds with those for two-year-olds revealed a different emphasis. Eighteen percent of items for 12-month-olds were language-based, in contrast to 51 percent of the items for 24- month-olds. The developmental decline among VLBW infants may be attributed to less than optimal home environments. On the other hand, it may be due to some as yet poorly understood influence of prematurity on language-based thought. The variable length of time in the intensive care nursery, the second most important factor identified in the model, may play a role in influencing development. The variable may act as either an overall index of perinatal illness or as an indirect indicator of the child's degree of prematurity. The large amount of unexplained variance, despite the comprehensive list of independent variables, suggests that further, definitive research is needed to sort out the nature and the extent of the environmental biological risk interplay.

Implications for research and practice

The importance of the home environment after discharge from the hospital compels nurses in primary and tertiary care settings to redouble their efforts

to educate parents in the care of their VLBW children from the children's earliest days. Nurses are challenged to develop programs that teach parents the beauty of the child's unfolding intelligence and competencies and the importance of the parental role in helping children to achieve their maximum abilities. Nurses need to develop and utilize educational materials that provide crucial information about supportive parenting behaviours in a package that is usable and effective. We must influence and formulate a social policy that empowers parents to give their best to parenting and that provides assistance when parental "best" is not enough.

This study should be replicated with a larger sample size and a normal birth weight control group that is matched for important variables such as birth order, parental intelligence and socioeconomic status. Additional research into the sequelae of VLBW should examine the impact of non-cognitive variables on children and families and should evaluate interventions that support optimal development. Studies should also be undertaken to identify specific cognitive processes that might identify children as being at risk for learning disabilities.

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RÉSUMÉ

L'influence des multiples facteurs de risque sur le développement des nourrissons de très faible poids à la naissance: observations portant sur les deux premières années de vie.

Cette étude longitudinale a pour objectif d'expliquer et de décrire l'influence dans le temps des facteurs médicaux, biologiques et environnementaux sur le développement d'enfants de très faible poids à la naissance (TFPN à 1 500 g). L'étude a porté sur 38 jeunes enfants TFPN (x poids à la naissance = 1 203 g) dont le poids à la naissance correspondait à l'âge gestationnel et qui ne présentaient aucune anomalie congénitale. Les données ont été obtenues du dossier du nourrison à la naissance et lors des visites à domicile alors que les enfants étaient âgés de 6, 12 et 24 mois. Les variables indépendantes sont le poids à l'unité de soins intensifs et le milieu familial. La variable dépendante est le progrès du développement au cours des deux premières années de vie. Trois instruments ont été utilisés dans cette phase de l'étude: le "Minnesota Child Development Inventory" (MCDI), le "Denver Developmental Screening Tool" (DDST), et le "HOME Observation for Measurement of the Environment" (HOME). Les données ont été traitées à l'aide d'une analyse de régression multiple, des tests t et une analyse "cross-lagged panel". On a pu expliquer une variance de 32% dans le développement de l'enfant par la combinaison de variables indépendantes. Le milieu familial a été le facteur responsable de la plus gande variance. Une analyse séparée des sous- échelles du milieu familial a révélé que, utilisées seules, elles expliquaient 47% de la variance du développement de l'enfant. Des jouets adéquats (0,69) et l'intervention maternelle auprès de l'enfant (0,40) ont été les variables environnementales les plus importantes. On a observé un déclin significatif des résultats du MCDI entre 12 et 24 mois. L'analyse "cross-lagged panel" qui a porté sur les données de 6 mois à 24 mois semble indiquer que le milieu familial est un facteur causal du développement chez les jeunes enfants de très faible poids à la naissance.