Prediction of IQ and Language Skill from Perinatal Status, Child Performance, Family Characteristics, and Mother-Infant Interaction

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Prediction of IQ and Language Skill from Perinatal Status, Child Performance, Family Characteristics, and Mother-Infant Interaction

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BEE, HELEN L.; BARNARD, KATHRYN E.; EYRES, SANDRA J.; GRAY, CAROL A.; HAMMOND, MARY A.; SPIETZ, ANITA L.; SNYDER, CHARLENE; and CLARK, BARBARA. *Prediction of IQ and Language Skill from Perinatal Status, Child Performance, Family Characteristics, and Mother-Infant Interaction.* CHILD DEVELOPMENT, 1982, **53,** 1134–1156. 193 basically healthy working-class and middle-class mothers and their infants participated in a 4-year longitudinal study which focused on the relative potency of several clusters of variables for predictions of intellectual and language outcome during the preschool years. The major results were: (1) Measures of perinatal or infant physical status were extremely weak predictors of 4-year IQ or language. (2) Assessments of child performance were poor predictors prior to 24 months, but excellent predictors from 24 months on. (3) Assessments of mother-infant interaction and general environmental quality were among the best predictors at each age tested, and were as good as measures of child performance at 24 and 36 months in predicting IQ and language. (4) Measures of the family ecology (level of stress, social support, maternal education) and parent perception of the child, especially when assessed at birth, were strongly related to child IQ and language within a low-education subsample, but not among mothers with more than high school education. Patterns of prediction were similar for 48-month IQ and 36-month receptive language; predictions were notably weaker for 36-month expressive language.

Longitudinal studies of infant and child development have had a somewhat checkered history within developmental psychology. After an early period of prominence in the 1920s, when a number of major studies were begun (including the Berkeley Growth Study, the Fels longitudinal study, and the Terman study of the gifted), longitudinal designs became less prominent for several decades, perhaps because the then current research questions could best be addressed with experimental and cross-sectional designs. In the late 1950s and early 1960s, however, several new longitudinal studies were begun that focused on the relationship between prenatal and perinatal variables, general cultural and economic conditions of rearing, and later outcomes for children. Werner's Kauai study, involving the entire cohort of infants born on the island of Kauai, Hawaii, in 1955 (Werner, Bierman, & French 1971; Werner & Smith 1977), and the National Collaborative Study, which involved collection of detailed prenatal and birth-record information on over 37,000 births (Broman, Nichols, & Kennedy 1975), are the most prominent examples of this new wave of longitudinal research.

Early results from these studies pointed to a number of basic conclusions about the relationship between perinatal status and later child outcomes. (1) Perinatal status variables such as low birth weight or anoxia had demonstra-

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ble, although modest, relationships with later poor cognitive or motor development (Smith, Flick, Ferris, & Sellman 1972; Werner et al. 1971). (2) The effect of perinatal status variables appeared to be mediated by the quality of the environment in which the child was reared. Data from both the Kauai study (Werner, Simonian, Bierman, & French 1967) and the collaborative study (Willerman, Broman, & Fiedler 1970) indicated that infants who had experienced high levels of perinatal complications showed poor cognitive functioning later primarily if they were also reared in poverty-level environments. (3) In most prospective studies, the single best predictor of later intellectual functioning was not perinatal status but the level of the mother's education (e.g., Smith et al. 1972).

It was already clear at the time these conclusions emerged that maternal education was only a marker for a whole range of differences in rearing environments provided in families. Yarrow and his colleagues (Yarrow, Rubenstein, Pedersen, & Jankowski 1972) had already shown that both the variety and amount of animate and inanimate stimulation provided in the home were important predictors of the child's cognitive development. The contingent or noncontingent delivery of stimulation (Lewis & Goldberg 1969); the style of interaction of parent and child (Bee, Van Egeren, Streissguth, Nyman, & Leckie 1969; Hess & Shipman 1967); the parents' perception of the child as better or worse than average (Broussard & Hartner 1970); and the overall conditions of family life circumstances, stresses, and emotional support (Wyler, Masuda, & Holmes 1971) had all been shown to be related to eventual cognitive outcomes for the child.

The collective impact of these findings was to create a research climate for more detailed short-term longitudinal studies of parent-infant interaction patterns, and of family environments. Notable among these are studies by Bradley and Caldwell (1976a, 1976b, 1977, 1978; Bradley, Caldwell, & Elardo 1979; Elardo, Bradley, & Caldwell 1975, 1977); Ramey and his colleagues (Ramey, Farran, & Campbell 1979; Ramey, Stedman, Borders-Patterson, & Mengel 1978); Clarke-Stewart (1973; Clarke-Stewart, Vanderstoep, & Killian 1979); Engle, Nechin, & Arkin (1975); and Wachs (1979). The immediate goal of these researchers was to uncover causal links between facets of the child's environment and later intellectual and language skill. A less emphasized but highly significant goal has been the eventual application of knowledge of such causal links to the task of early identification or screening of children or families at high risk for later intellectual or linguistic problems (Bradley & Caldwell 1978; Ramey, MacPhee, & Yeates, in press).

Results from these studies point to specific aspects of the environment that appear to be particularly significant for predicting the child's concurrent or later intellectual or language skill, including provision of sufficient and appropriate play materials (Bradley & Caldwell 1976a; Clarke-Stewart 1973; Wachs 1979; Yarrow, Rubenstein, & Pedersen 1975); affectionate, nonrestrictive, and nonpunitive caregiving (Beckwith, Cohen, Kopp, Parmelee, & Marcy 1976; Bradley & Caldwell 1976a; Clarke-Stewart 1973; Clarke-Stewart et al. 1979; Ramey et al. 1979); and verbal stimulation of and responsivity to the child (Bradley & Caldwell 1976; Clarke-Stewart 1973; Clarke-Stewart, Vanderstoep, & Killian 1979; Elardo, Bradley, & Caldwell 1977; Engel et al. 1975). Mitzl (1980) has reinforced the importance of verbal stimulation from parents with her recent finding that children's Bayley scores can be increased when parents are given special training in language stimulation.

While these findings provide considerable support for the widely held assumption that qualities of the child's environment are crucial for cognitive and language development, a number of questions remain open. Since the present study was begun in the early 1970s at about the same time as many of the other recent short-term longitudinal studies, it shares much of the basic reasoning evident in the work of Bradley and Caldwell, Ramey, and others. However, it includes several features that permit us to address questions not widely examined in the contemporaneous research, as well as to add to the basic fund of knowledge concerning environment/outcome links.

First, since we assessed the child's status (at birth, and at repeated intervals thereafter) as well as the quality of the environment, we are in a position to address the question of the relative usefulness of information about the child versus information about the environment in predicting later functioning. The early longitudinal studies that focused on perinatal status, such as the Kauai study and the Collaborative Perinatal Project, did not include detailed assessments of parent-infant interaction. Recent studies focusing on interaction or on general environmental quality have not typically assessed the child either at birth or extensively at

later ages. This question has considerable practical relevance for those wishing to identify children with prospective problems: should we focus our energies on detailed assessment of the child in infancy and toddlerhood, or are we better-off attempting a detailed look at the environment in which the child is nurtured? There is considerable dispute in the literature concerning the usefulness of infant mental tests for predictions of later IQ or other cognitive skill. McCall (1979, 1981), for example, has argued that we should abandon the search for links between infant behavior and later IQ, but Siegel (1981) has recently offered evidence of substantial correlations between Bayley mental and psychomotor indices obtained in the first year of life and 24-month Bayley and Reynell language scores. What is more, the correlations between the early infant and later infant test scores are stronger in Siegel's sample than are the correlations between a measure of the home environment (Caldwell's HOME inventory) and 24-month Bayley or language scores. Data from the present study of largely term infants allow us to take another look at this question.

A second issue of interest in the present study, which has not been widely addressed by other researchers, is the predictive role of more general demographic or "ecological" family characteristics (to use Bronfenbrenner's term [1977]). We know that maternal education is consistently related to child outcomes. But what about other aspects of the family, such as the amount of social support available to the mother, or the amount of life change experienced by the family? And what about the mother's beliefs about children and her perceptions of her own child as elements in the equation? Does knowledge of these aspects of the mother's environment and of her perception of the child tell us more about the child's likely outcome than we would know simply from asking the mother how many years she went to school? And how well does this cluster of variables compare in predictive power with measures of mother-child interaction, or assessments of the child's status or performance?

The first two issues we have discussed touch on the question of what should be assessed if we are to achieve the maximum prediction of the child's later functioning. But an equally important question seems to us to be when to assess. If one's purpose, eventually, is to screen families and children so that ameliorative services can be offered at a time when habilitation and remediation are still possible, then arguably the earlier we are able to make useful predictions the more effective the screening will be. But we know little about the relative helpfulness of perinatal data versus data collected at 4, or 12, or 24 months of age. As a general rule, of course, we would expect that later assessments would be more strongly related to 3-, or 4-, or 5-year-old functioning in the child. But perhaps it is nonetheless possible to collect useful data at birth, or during the first year of life.

Finally, we have been interested in possible differences in the predictive equations for mothers who differ in level of education. As Ramey et al. (1979) point out, the samples assessed in most studies linking early environment with later child functioning have been heterogeneous with respect to social class or maternal education. Since we know that there are social class or maternal education differences in family interaction on precisely those dimensions found predictive of later IQ, we cannot be sure whether we are describing relationships that would be applicable within each social class/education group, or whether we are merely providing further description of the parent-education differences in children's cognitive accomplishments. Kagan (1979; Kagan, Kearsley, & Zelazo 1978) has recently argued that observed consistencies between early and later childhood measures of intellectual skill are essentially artifacts of social class variation. At the very least, if we are to move closer to statements of causal connections between environmental measures and measures of the child's intellectual development, we must be able to show that the significant environmental variables are predictive within as well as across social class groups. There is some existing evidence for such intragroup predictability. Ramey et al. (1979) report such relationships with a homogeneous lower-class sample; Hess, Shipman, Brophy, and Bear (1969) found relationships between mother-child interaction patterns at 4 years and the child's later school performance within each of four social class groups. However, the data base is not large. Since the sample in the present study is sufficiently large to enable us to examine results separately for different levels of maternal education, we can add to this body of information.

In sum, while the basic design of the present study is similar to that of several other contemporaneous longitudinal studies that have examined the links between early environment and later intellectual linguistic functioning, the size of the sample we have followed, the unusually wide range of measures used, and the

frequency of observation we employed allow us to explore a wider series of questions than have been addressed by others.

Method

Subjects

Subjects were 193 primiparous mothers and their infants, selected from among births during 1973 and 1974 at a large Health Maintenance Organization (HMO) hospital in Seattle, Washington. Maternal education was used as a blocking variable in subject selection in order to achieve a sample that would include about half (84) who had high school education or less (the median value for members of the HMO), and about half who would have more than high school education (109). The presence or absence of perinatal risk factors was also used as a blocking variable, with 80 women selected from among those who had experienced no complications of pregnancy or delivery, and whose infants showed no postnatal complications. The remaining 113 mothers had experienced at least one complication during pregnancy or delivery (e.g., weight gain over 40 pounds, cesarian-section delivery, urinary infection during pregnancy, etc.), or their infants had shown at least one postnatal complication (e.g., Apgar of 6 or below, birth weight below 2,500 grams, etc.). Multiple births and infants with life-threatening congenital anomalies were excluded. We should emphasize that despite the use of perinatal complication as a basis for subject selection, this is an unusually healthy sample. Only three of the infants had birth weights below 2,500, and only 23 had Apgar scores of 6 or below at 1 or 5 min. Only 14 of the mothers had had previous stillbirths or neonatal deaths, and only 10 had a chronic health problem during the pregnancy. Eleven births were by cesarian section (5.6%), which is well below present rates. Because the sample is, thus, basically homogeneous on perinatal risk, we have combined the no-risk and some-risk groups into a single sample for all analyses.

Similarly, despite the intentional variation in maternal education within the sample, the group as a whole is fairly well educated and economically well-off. The mothers average 13.9 years of education (SD = 2.5), the fathers 14.9 years (SD = 3.1). The mothers averaged 24.9 years of age at delivery (SD = 4.3), and the median family income was $11,000–$12,000 in 1973. The majority (93.3%) were married at the time of intake into the study, 85% were Caucasian, and 51.5% had female children.

It is important for us to underline the fact that this is a healthy, working- and middle-class sample. We are attempting, in essence, to make differential predictions within a generally low-risk group. The drawback to such a sample is that we cannot know whether any lack of findings are due to the restriction of range in the sample; the advantage is that any relationships we do find may be the more striking because they occur within a relatively low variability group.

Subject recruitment.—Initial contact with prospective subjects normally occurred in the prenatal clinic at the hospital at the time of the 8-month prenatal visit. Mothers were notified about the study, and those who were interested discussed the study at greater length with study personnel in the clinic. Those mothers who expressed an interest in participating in the study completed a questionnaire at that time. At delivery, if the mother and infant continued to meet the study criteria, and if there had not been more than three deliveries that day among prospective subjects (since we could not test more than three in 1 day), the mother and infant remained as part of the study sample. A number of mothers (39 out of 193), who had expressed some apprehension about involvement in a long-term study before they knew the outcome of the pregnancy, were contacted again in the hospital and completed the antepartum data retrospectively.

Sample Attrition

Considerable effort was expended to maintain contact with all subjects, so attrition rates have been relatively low, as is evident in table 1. Attrition has obviously been greatest in the low-education subsample, from which 15 subjects have been lost (18%). This is also the group for which we are most likely to have missing data from early data points, since these mothers were somewhat less cooperative about returning questionnaires and keeping appointments.

General Data Collection Procedures

Observation and assessment of families and children occurred at the eighth month of pregnancy (for most subjects); at birth; and at 1, 4, 8, 12, 24, 36, and 48 months. At each of these ages except prenatal, birth, and 24 months, a 1–2-hour home visit was conducted; at 12, 24, 36, and 48 months the child was also seen in a university laboratory setting for individual assessment. At birth, the child's physical status was assessed by study personnel in

TABLE 1

ATTRITION FROM THE SAMPLE DURING EACH YEAR OF THE STUDY AFTER DELIVERY

TIME SINCE DELIVERY	NUMBER REMAINING IN EACH GROUP					
	High Education		Low Education		Total Sample	
Original sample	109	(100)	84	(100)	193	(100)
1 year	105	(96)	72	(86)	177	(92)
2 years	97	(89)	64	(76)	161	(83)
3 years	95	(87)	72	(86)	167[a]	(86)
4 years	100	(92)	69	(82)	169[a]	(87)

NOTE.—Figures shown in parentheses are percentages.

[a] At 3 and 4 years additional efforts were made to test children who were no longer living in the Seattle area; thus, the sample size increased somewhat at these points in time.

the hospital and through medical chart examination.

To reduce the amount of information to convey and the number of variables to include in analyses, in the present report we will omit data from the 1- and 8-month data collections. Findings from the 4-month observation are similar to those obtained at 1 and 8 months, so reporting on only one data point from the first year seems reasonable.

The measures included in the study can be grouped into four clusters, based on our interest in the relative predictive power of several classes of variables: (1) assessments of perinatal status, and of the infant's physical status in the early months of life; (2) measures of the child's "outcome," including scores on standardized instruments assessing mental, linguistic, and interpersonal skills; (3) measures of the "ecological" characteristics of the family, and of the mother's perception of the infant; and (4) assessments of parent-infant interaction and of general environmental quality.

Since the list of measures and variables included in the study is lengthy, in the following description we will provide only brief information about widely used or well-standardized instruments; details concerning instrument development and reliability will be given only for those instruments developed specifically for this research, or for less well-known instruments developed by others.

Instruments and Variables

Perinatal and infant status.—The infant's gestational age was estimated following the procedure developed by Dubowitz (Dubowitz, Dubowitz, & Goldberg 1970), which yields an estimated weeks of gestation score. Weight, length, head circumference at birth, Apgar score at 5 min, and sex were obtained directly from the hospital chart. A summary perinatal risk score was also constructed by simply summing the total number of individual prenatal, perinatal, and postnatal complications observed in the mother or the infant, out of a list of 36. The scores on this variable ranged from 0 to 6, with a mean of 1.19.

Assessment of minor congenital anomalies, based on the work of Smith (1970) and Waldrop (Waldrop & Goering 1971; Waldrop, Pedersen, & Bell 1968), were done at the 4- and 8-month home visits, with anomalies of the mouth, hands, and feet assessed at 4 months; and of the ears, eyes, and head at 8 months. Eighteen characteristics were noted and given scores varying from 0 to 2 (see Barnard & Douglas [Note 1] for scoring weights and procedures). The summed weighted scores comprised the total anomalies score.

The Brazelton Neonatal Behavioral Assessment Scale was administered by Brazelton-trained examiners on the second postpartum day, normally midway between regular feedings. The scores from this test used in the analyses reported here were seven cluster scores developed by Lester (Note 2): orientation, regulation of state, habituation, motor skills, autonomic stability, range of state, and abnormal motor reflexes.

The final variable in this cluster is a measure of the child's sleep/wake patterns during the first year of life, as an additional reflection of physiological status. During the week following each home visit, the mother recorded the infant's sleep periods, times of distress, awake-happy periods, and her own caregiving activities. Inspection of the relationships among these variables suggests that the measures of

sleep and wakefulness were highly correlated so that a single measure, night awakenings, can be used to describe this dimension. The score is the number of times per night that the mother said the child awakened, averaged over the 7-day recording period. A high score on this dimension reflects poor infant regulation of state.

Child outcome measures.—Mental development was assessed with the Bayley Scales of Infant Development (BSID) (Bayley 1969) at 12 and 24 months, and with the Stanford-Binet (Terman & Merrill 1973) at 48 months. Motor development was assessed using the psychomotor development scale of the Bayley scales at 12 and 24 months, the Denver Developmental Screening Test (Frankenberg & Dodds 1967) at 36 months, and the motor section of the McCarthy Scales of Children's Abilities (McCarthy 1972) at 48 months. Receptive and expressive language skills were assessed using the Sequenced Inventory of Communication Development (Hedrick, Prather, & Tobin 1975) at 12 and 36 months. At 24 months, 10 items from the Bayley scales that assess aspects of language skill were used to generate language scores, and at 48 months, the Fluharty Speech and Language Screening Test (Fluharty 1974) was used. Each of these tests yields separate scores for expressive and receptive language.

We assessed the child's social/emotional development at 36 and 48 months using the Preschool Behavior Questionnaire (Behar & Stringfield 1974). This instrument, which included 30 descriptive words or phases (e.g., restless, irritable, disobedient, fussy, tells lies), was originally designed to be filled out by preschool teachers. The teacher indicates whether each item is not present, sometimes applies, or certainly applies to a particular child. In the present study, the form was filled out by mothers. Comparison of use of the instrument by mothers and teachers in a separate pilot study (Gray, Clancey, & King, in press) suggested that mothers checked more items as applicable than teachers did, but that the factor structure was similar for mothers and teachers. Only the total score, which describes the amount of "deviant" behavior shown by the child (as perceived by the mother) was used in the present analysis.

The child's physical health was assessed indirectly during the interviews at 12, 24, 36, and 48 months by asking the mother to describe the number of illnesses and the number of medically attended accidents the child had had the previous year.

Ecological and parent perception variables.—Maternal education was used as the major demographic descriptor of the families for these analyses. In addition, we inquired about the overall stresses on and positive functioning of the families in a number of ways. Family stress was assessed using the Schedule of Recent Events (SRE) developed by Holmes and Rahe (1967). In the normal administration of this instrument, the total score is the sum of weighted scores for 42 potential life changes the respondent reports having experienced in the previous 12 months. In our study, mothers completed the SRE at each assessment point except 24 months. At each contact, mothers described life changes for the previous 12 months, or since the last contact, whichever was the most recent. At 36 months, the mothers filled out the list twice, once reflecting the period from 24 to 36 months, and once reflecting the period from 12 to 24 months.

Three scores obtained from the maternal interview reflected the more positive aspects of family functioning: social support prenatally, social support at 4 months, and positive attitudes toward pregnancy. The social support measure at both ages is heavily loaded with items touching on the mother's perception of the father's support (e.g., "father shared mother's concerns," "father gave most emotional help") but also included more general support (e.g., "mother had enough emotional help"). Information from eight interview items was included in the prenatal social support score, and five items were included at 4 months. Internal consistency (Cronbach's alpha) was .77 for the prenatal score and .39 for the 4-month score. The positive pregnancy score included information from five interview questions and basically reflects the mother's positive versus negative attitude about her pregnancy. The alpha for this score was .51.

The mother's perception of her infant and her general expectations about children were assessed in two ways. The Neonatal Perception Inventory (NPI), developed by Broussard (Broussard & Hartner 1970), was administered at 2 days and at 1 month, following Broussard's procedure. The mother was asked to rate her own baby on several dimensions and also rate an "average" baby. For the variable derived, a high score indicates that a mother thought her infant was better than the average baby. Although Palisin (1980), using subjects from the present sample, was unable to replicate Broussard's basic finding that mothers who rate their

infants as equal to or worse than average have children with later higher risk of emotional disturbance, we have nonetheless retained this variable, at both birth and 1 month, for the present analysis. The final measure in this group, developmental expectations, was developed for this project. The mother was asked, before the birth of the child, to give an estimate of the age at which the infant will first see, hear, learn, become aware of surroundings, and profit from hearing people talk to him. The score is the sum of the number of weeks-of-age the mother estimated, so a high score indicates a mother thought these things happened relatively late.

Parent-infant interaction and environmental quality measures.—The broadest assessment we obtained of the total home environment was with the HOME Inventory (Caldwell & Bradley, Note 3). The items included in this now widely used instrument describe observed mother-child interaction patterns, family habits, and living patterns as described by the mother, and observed aspects of the orderliness and enrichment of the home. The total score from this assessment, which is the only variable we have used in the present analyses, should be thought of as a broad-gauge measure of the overall stimulating quality of the child's home environment. However, since many individual items do reflect actual patterns of interaction between mother and infant, we have included this measure in the category of "parent infant interaction" variables.

Two versions of the HOME were used, the infant version at 4, 12, and 24 months, and the preschool version at 36 and 48 months. At every age except 24 months the normal procedure was followed, with the items completed by an interviewer/observer in the home. Since no home visit was made at 24 months, a revised method was used at that data point. Items normally obtained by interviewing the mother were revised into the form of multiple choice and open-ended questions, and were included in a questionnaire filled out by the mother. Observation items were completed by an interviewer who had seen the mother and child interact during the clinic visit. Two items which could not be translated into either form were omitted. The questionnaire/observation measure has not yet been compared directly with the home observation/interview version on the same sample of subjects. However, we have compared the predictive correlations between the total score on the 2-year HOME and 4-year Binet from the present study with those obtained by Bradley and Caldwell (1976a) using the normal version of the HOME at 2 and the Binet at 54 months. Since the correlations were of the same order of magnitude for the two studies (.60 and .57, respectively) it suggests that the questionnaire/interview and the home visit procedures are yielding comparable information.

To assess specific aspects of mother-infant interaction, two additional instruments were developed for this study, feeding interaction scales and teaching interaction scales. Observations of feeding were made in the home at 4 and 12 months, with the home visit arranged so that a normal feeding time fell within the visit. The mother was asked to arrange as normal a feeding as possible, and to tell the observer when she was done. The mothers were told only that we were interested in the "various styles mothers and infants have." At the completion of the feeding, the observer (who had been silent throughout) immediately filled out the scales, then answered the mother's questions and gave supportive comments.

For each feeding observation, 21 seven-point scales (11 maternal and 10 infant scales) were scored, with the midpoint representing usual or expected behavior. The scales describe the ways the mother sets up the environment for feeding, the attentiveness or distractibility of the mother and infant, the modes of stimulation and response used, the mood, tension, and irritability of the mother and baby, and the give and take of control of the interaction (details are provided in Barnard & Eyres [Note 4]).

The 21 scales were reduced to a single feeding score for the mother and one for the infant at each data point by first "folding" each scale so that the optimum behavior was scored highest, and any deviation from the optimal was scored lower, and then summing these scores across all scales for each participant. The mother's feeding score thus describes her sensitivity and adaptability to the infant; the infant's feeding score describes his adaptability and responsiveness. Cronbach's alpha for the total mother score was .86 at 4 months and .80 at 12 months; for the infant scores, alpha was .70 and .67 at the same two ages. Interobserver reliability coefficients were obtained for the total scores by computing correlations across items for each session. The mean interobserver correlations ranged from .70 to .83.

At each contact point from 1 to 48 months, the mother was also asked to teach her child

two tasks which had been chosen from the Bayley scales or from equivalent sensorimotor tests (e.g., putting three blocks in a cup, drawing a line on a paper, reaching for a ring). One task was appropriate to the age of the child (the "easy task"), while a second was 1.5–2.5 months in advance of the child's age level (the "hard task"). Except at 24 months, when the teaching observation occurred during the clinic visit, all observations were carried out at home. The mother was told, "I have two tasks I would like you to help [child's name] learn. You can do this in any way that you like. You may position [child's name] in any way you like and take as much time as you wish. Just let me know when you are finished with the first task and then I will take a few notes and give you the second task." The easy task was always given first.

The observer completed 24 five-point scales for each task, 15 of which describe maternal behavior, and nine of which describe child behavior. Factor analysis of the maternal scales suggested the existence of four clusters that were reasonably consistent over age: positive messages, negative messages, task facilitation, and instructional techniques. The 12 items that entered into these clusters were subsequently averaged across the two tasks to yield a total maternal teaching score. In order for the total teaching score to reflect "optimum" teaching, scale scores for items reflecting negative messages (negative feedback and disapproval) were reversed. In addition, because the items in the "techniques" cluster appeared to reflect intrusiveness on the part of the mother, rather than sensitive teaching, items in this cluster were also reversed. A high total score thus reflects high positive messages, good task facilitation (timing and sensitivity), low negative messages, and low levels of intrusive techniques.

Factor analysis of the infant scales suggested the existence of a single consistent cluster, originally labeled "readiness to learn." It includes ratings of the child's attentiveness to task help, intensity and duration of task involvement, and alertness. The scores on these four items were averaged across the easy and hard tasks to yield a single infant teaching score.

Cronbach's alpha for the total mother teaching score ranged from .77 to .80 at the several data points, while alphas for the child teaching score ranged from .76 to .89. Interobserver reliability coefficients ranged from .79 to .83.

Summary of Measures and Variables

Table 2 summarizes the variables, data sources, and ages at which each assessment was made for those variables included in the present report. We have also shown the total number of variables at each data point—a figure that becomes relevant when we enter these variables into multiple regressions.

Comparisons of Magnitude of Correlations

Complex longitudinal studies such as this one, in which large numbers of correlation coefficients are reported, pose special problems of interpretation. To avoid placing undue emphasis on individual correlations, we have generally looked for patterns of relationship that hold across measures, or across time points. In some instances, however, it has seemed appropriate to compare the magnitude of individual pairs of correlations directly by converting r to z and testing for the significance of the difference between z's using a t test. As a general rule, whenever we wished to make a point about "stronger" predictions from one variable or group of variables than another, we have used such direct comparisons. Where more general descriptive statements are used, these are ordinarily based on an examination of the pattern of correlations.

Results

Means, standard deviations, sample sizes, and education differences are given for all variables in table 3. We have also indicated those few variables on which sex differences were obtained. The findings indicate that mothers with more than high school education, in comparison with those with high school or less, had somewhat larger and more motorically mature newborns, their infants had significantly higher mental test and language test scores beginning at 24 months of age, and they provided a more enriched environment and more facilitative teaching from the earliest observation. The better-educated mothers also reported that they had more social support during their pregnancies, and had earlier expectations for their infants—they thought their babies would be able to see, hear, and learn sooner than did less well-educated mothers. Note, as well, several variables on which education differences did not appear. In keeping with the findings of other researchers (cf. Bayley 1965; Farran & Ramey 1980; Golden, Birns, Bridger, & Moss 1971) we found no education differences in mental or language development earlier than 24 months, and no differences in psychomotor functioning

at any age. There were also no significant differences in level of life change experienced by the two education groups, although the scores on these measures were consistently higher for the less well-educated mothers. In sum, except for size at birth, infants born to better-educated or less well-educated mothers did not differ on any measures during the first 2 years of life, despite the fact that environmental and parent-infant interaction measures show differences beginning as early as 4 months, and measures of parent perception differ at birth.

Predictions of IQ and Language Skill

In examining predictive relationships between early measures and later outcomes, we have focused our attention in the present report on prediction of three outcomes: 48-month Binet IQ, and receptive and expressive language scores at 36 months. The 36-month language scores, rather than the 48-month scores, were selected for two reasons. First, language is in a greater state of change at the earlier age so that we can expect greater variability among children. Second, the measure used at 36 months (the Sequenced Inventory of Communication Development) is a more sensitive instrument than is the Fluharty, which we used at 48 months. The latter is basically a screening test on which nearly all of our subjects scored at or near the ceiling. The 36-month scores thus

TABLE 2

SUMMARY OF VARIABLES, DATA SOURCES, AND TIMES OF ASSESSMENT

VARIABLES AND INSTRUMENT OR DATA SOURCE		TIMES OF ASSESSMENT IN MONTHS AND NUMBER OF VARIABLES					
		Perinatal/ Newborn	4	12	24	36	48
Perinatal and infant status:							
Gestational age	(Dubowitz)	1	...	...	...	...	...
Weight, length, head circumference, Apgar score	(hospital records)	4	...	...	...	...	...
Sex	(hospital records)	1	...	...	...	...	...
Minor congenital anomalies	(direct observation)	1[a]	...	...	...	...	...
Mother-infant risk score	(hospital records and interview)	1	...	...	...	...	...
Night awakenings	(sleep/activity record)	...	1	1	...	...	...
Brazelton assessment scores	(Brazelton Neonatal Assessment)	7	...	...	...	...	...
Child outcomes:							
Mental development	(Bayley; Binet)	...	...	1	1	...	1
Psychomotor development	(Bayley; Denver; McCarthy)	...	...	1	1	1	1
Receptive language	(Bayley; Sequenced Inventory; Fluharty)	...	...	1	1	1	1
Expressive language	(Bayley; Sequenced Inventory; Fluharty)	...	...	1	1	1	1
Problem behavior	(Behar PBQ)	...	...	...	...	1	1
Illnesses/accidents	(maternal interview)	...	...	2	2	2	2
Family ecology and parent perceptions:							
Maternal education	(interview)	1	...	...	...	...	...
Neonatal perception	(Broussard inventory)	2[b]	...	...	...	...	...
Developmental expectations	(interview)	1	...	...	...	...	...
Social support	(interview)	1	...	...	...	...	...
Positive pregnancy	(interview)	1	...	...	...	...	...
Life change	(Schedule of Recent Events)	1	1	1	1	1	1
Parent-infant interaction and environmental quality:							
Total HOME score	(HOME inventory)	...	1	1	1	1	1
Total mother teaching score	(teaching observation)	...	1	1	1	1	1
Total child teaching score	(teaching observation)	...	1	1	1	1	1
Total mother feeding score	(feeding observation)	...	1	1	...	...	...
Total child feeding score	(feeding observation)	...	1	1	...	...	...
Total number of variables at each time point		22	8	13	10	10	11

[a] For convenience, the data for the minor congenital anomalies scores were actually collected when the infants were 4 and 8 months old, but this variable is traditionally considered a perinatal variable.

[b] One neonatal perception score was obtained at birth, and a second at 1 month, following Broussard's plan; both are included as perinatal variables.

TABLE 3—MEANS, STANDARD DEVIATIONS, AND EDUCATION DIFFERENCES FOR ALL VARIABLES INCLUDED IN THE ANALYSES

VARIABLE AND TIME OF ASSESSMENT	TOTAL GROUP			HIGH EDUCATION			LOW EDUCATION			SIGNIFICANT DIFFERENCES
	N	*M*	SD	*N*	*M*	SD	*N*	*M*	SD	
Perinatal and infant status variables:										
Gestational age (perinatal)	193	39.2	1.4	109	39.3	1.2	84	38.0	1.6	...
Weight at birth (grams)[a]	188	3,382	309	107	3,470	547	81	3,266	570	< .05
Length at birth (inches)	179	20.3	1.3	99	20.6	1.3	80	20.1	1.3	< .01
Head circumference[a]	173	34.0	1.7	98	34.2	1.6	75	33.8	1.8	...
Apgar score (5 min)	184	8.9	.9	106	8.9	.9	78	8.9	.8	...
Minor anomalies	164	3.2	2.0	100	3.2	2.0	64	3.2	1.9	...
Perinatal risk score	193	1.2	1.4	109	1.1	1.3	84	1.3	1.4	...
Brazelton habituation	168	6.0	1.2	95	6.1	1.1	73	5.9	1.4	...
Brazelton orientation	189	5.9	1.5	108	5.8	1.4	81	6.0	1.5	...
Brazelton motor score	193	5.0	.8	109	5.1	.8	84	4.8	.9	< .01
Brazelton range of state	193	4.0	.8	109	4.1	.8	84	3.9	.9	...
Brazelton regulation of state	193	6.4	1.4	109	6.5	1.3	84	6.2	1.4	...
Brazelton autonomous stability	193	5.0	1.3	109	5.1	1.3	84	4.8	1.2	...
Brazelton reflexes	193	2.4	2.2	109	2.3	2.1	84	2.4	2.3	...
Night awakenings (4 months)	139	.7	.7	93	.7	.7	46	.8	.7	...
Night awakenings (12 months)	112	.4	.5	83	.3	.4	29	.5	.7	...
Infant outcome variables:										
Bayley MDI (12 months)	173	117.0	10.7	104	117.6	9.0	64	116.2	12.9	...
Bayley MDI (24 months)	159	116.8	18.2	96	121.0	16.3	63	110.3	19.1	< .001
Binet IQ (48 months)	163	114.2	16.8	100	118.3	16.6	63	107.6	15.0	< .001
Bayley PDI (12 months)	173	101.3	14.4	104	101.8	14.7	69	100.6	14.0	...
Bayley PDI (24 months)[a]	155	110.8	14.3	93	112.5	12.9	62	108.2	15.9	...
Denver motor score (36 months)	162	100.0	15.0	90	98.4	13.4	72	102.1	16.6	...
McCarthy motor (48 months)	159	52.4	8.4	92	53.0	8.4	67	51.5	8.3	...
Receptive language (12 months)	168	3.2	.7	103	3.1	.7	65	3.3	.7	...
Receptive language (24 months)	159	81.1	28.6	96	87.9	24.2	63	70.7	31.9	< .001[b]
Receptive language (36 months)	164	100.0	15.0	92	104.9	11.5	72	93.6	16.5	< .001[b]
Receptive language (48 months)[c]	150	9.1	1.1	94	9.2	1.0	66	9.0	1.3	...
Expressive language (12 months)	168	4.2	.7	103	41.0	.6	65	4.3	.7	...
Expressive language (24 months)[c]	159	81.8	28.9	96	88.3	24.2	63	71.9	32.5	< .001[b]
Expressive language (36 months)	164	100.0	15.0	92	104.9	11.5	72	93.6	16.5	< .01[b]
Expressive language (48 months)[c]	160	9.6	.9	94	9.7	.9	66	9.5	.8	...
Disturbed behavior (36 months)	175	15.6	5.9	102	15.6	5.7	73	15.6	6.2	...
Disturbed behavior (48 months)	169	15.6	6.5	100	15.9	6.1	69	15.2	6.9	...
Accidents (12 months)	161	.1	.5	99	.2	.5	62	.1	.4	...
Accidents (24 months)	161	.2	.5	99	.2	.5	62	.3	.5	...
Accidents (36 months)	174	.2	.4	101	.2	.4	73	.2	.5	...
Accidents (48 months)	167	.2	.4	99	.2	.5	68	.2	.4	...
Illnesses (12 months)	161	5.7	2.7	99	5.8	2.8	62	5.4	2.6	...

[a] Boys significantly higher on this variable, $p < .05$.

[b] Variances for high- and low-education groups differ significantly; t calculated with separate variance estimates.

[c] Girls significantly higher on this variable, $p < .05$.

TABLE 3 (*Continued*)

Variable and Time of Assessment	Total Group			High Education			Low Education			Significant Differences
	N	*M*	SD	*N*	*M*	SD	*N*	*M*	SD	
Illnesses (24 months)	161	3.3	3.5	99	3.8	3.6	62	2.4	3.1	< .05
Illnesses (36 months)	162	2.3	1.4	94	2.4	1.3	68	2.2	1.5	...
Illnesses (48 months)	167	.8	1.1	99	1.0	1.1	68	.7	1.0	< .05
Ecological and parent perception variables:										
Mother's education	190	14.0	2.6	108	15.8	1.8	82	11.6	.8	< .001[b]
Neonatal perception (newborn)	187	1.9	2.0	104	1.8	2.0	83	2.0	2.1	...
Neonatal perception (1 month)	189	2.2	2.7	107	2.4	2.6	82	2.0	2.9	...
Developmental expectations (newborn)	174	8.1	6.1	101	6.9	4.8	73	9.6	7.3	< .01[b]
Positive pregnancy (newborn)	182	3.1	1.1	105	4.0	1.1	77	3.8	1.1	...
Social support (perinatal)	182	6.9	1.7	105	7.2	1.3	77	6.5	2.0	< .05[b]
Social support (4 months)	169	3.8	1.2	104	3.8	1.2	65	3.7	1.2	...
Life change (perinatal)	180	212.4	153.8	105	207.4	137.0	75	219.4	175.4	...
Life change (4 months)	179	76.2	76.6	105	67.0	70.1	74	89.4	83.6	...
Life change (12 months)	173	78.6	75.6	105	74.0	67.5	68	85.9	86.7	...
Life change (24 months)	166	76.4	79.7	96	73.1	76.9	70	81.0	83.8	...
Life change (36 months)	175	168.0	124.3	102	157.9	120.0	73	182.1	129.6	...
Life change (48 months)	169	191.7	132.7	100	179.2	135.4	69	209.7	127.4	...
Interaction and general environment variables:										
Mother teaching score (4 months)	178	3.7	.3	105	3.7	.3	73	3.6	.3	< .05
Mother teaching score (12 months)	159	3.6	.3	97	3.7	.3	62	3.5	.4	< .001
Mother teaching score (24 months)	154	3.6	.2	91	3.7	.2	63	3.6	.2	< .001
Mother teaching score (36 months)	166	3.7	.3	94	3.8	.2	72	3.6	.3	< .001
Mother teaching score (48 months)	162	3.7	.3	95	3.8	.2	67	3.7	.3	< .05
Infant teaching score (4 months)[a]	178	3.8	.7	105	3.8	.7	73	3.9	.7	...
Infant teaching score (12 months)	159	3.9	.6	97	4.9	.5	62	3.9	.6	...
Infant teaching score (24 months)	154	3.8	.6	91	3.8	.6	63	3.8	.5	...
Infant teaching score (36 months)	166	4.7	.4	94	4.7	.4	72	4.7	.4	...
Infant teaching score (48 months)[a]	162	4.4	.6	95	4.5	.5	67	4.4	.6	...
Mother feeding score (4 months)	158	38.4	6.2	95	39.1	5.3	63	37.3	7.2	...
Mother feeding score (12 months)	146	34.5	3.5	91	35.0	3.5	55	33.7	3.3	< .05
Infant feeding score (4 months)	158	26.4	3.3	95	26.1	3.2	63	26.9	3.4	...
Infant feeding score (12 months)	146	28.4	2.5	91	28.7	2.4	55	28.0	2.6	...
Total HOME score (4 months)	178	32.7	5.1	105	34.3	3.8	73	30.4	5.7	< .001[b]
Total HOME score (12 months)	169	36.3	5.6	103	38.4	3.5	66	33.0	6.5	< .001[b]
Total HOME score (24 months)	140	37.9	3.5	86	39.1	2.6	54	36.1	4.1	< .001[b]
Total HOME score (36 months)	164	44.3	6.7	93	47.0	4.4	71	40.7	7.4	< .001[b]
Total HOME score (48 months)	161	45.3	6.5	96	47.6	41.0	65	41.9	7.9	< .001[b]

give us outcomes on which we have reasonable variation.

The significant correlations between the variables in the four clusters and these three outcomes are given in table 4. Only those variables for which at least one of the three predictive relationships was significant are listed in the table. Several points are worth emphasizing about these findings. First, the magnitude of most of the correlations is small; no single measure of perinatal status, child outcome, family ecological characteristics, or interaction pattern accounts for very much of the variance in IQ or language skill (there is no magic bullet!).

Second, within this relatively healthy sample, neither traditional measures of the infant's physical status at birth, such as birth weight or Apgar score, nor assessments of the infant's postnatal characteristics, such as the Brazelton scores, predicted the child's later IQ or language skill. Of 17 perinatal and infant status variables included in this analysis, only one, the total mother-infant risk score, was significantly (and weakly) related to any of the three outcomes.

Third, with several notable exceptions, later measures were more strongly related to the three outcomes than were early measures. For example, 12-month measures of MDI, receptive, and expressive language were only very slightly predictive of the three outcomes, while at 24 months these same predictors were markedly more potent. In seven of the nine contrasts (12- vs. 24-month scores for each of three predictors with each of three outcomes), the 24-month prediction is significantly higher ($p < .05$). Similarly, for both the HOME score and the mother's teaching score the predictive correlations were generally larger for the 12- and 24-month assessments than for the 4-month measures, although the differences among r's are significant only for predictions of IQ. This pattern does not hold for the mother's feeding score, however, which was only very slightly related to any of the outcomes at any age.

The exceptions to the "later measures are better" pattern appear to be several of the ecological/parent perception measures obtained prenatally or at the time of the child's birth. In particular, the mother's perception of her social support prenatally was strongly related to receptive language ($r = .43$, $p < .001$), and somewhat less strongly to IQ ($r = .31$, $p < .001$). The mother's developmental expectations were also fairly strongly related to receptive language development ($r = -.35$, $p < .001$). That is, mothers who thought that their infants would see, hear, learn, and profit from being talked to relatively early in life had infants who later understood language somewhat better.

Given the typically small magnitude of the individual correlations in table 4, the obvious next step is to combine the information from several variables using multiple regression analyses. We have done this in two ways. First, in order to address the question of what to measure in predicting later intellectual and linguistic performance in the child, we have combined variables in each of the four clusters into a separate regression for each outcome variable. Second, to address the question of when to assess, we have combined variables across clusters at each assessment point.

Comparing the four clusters.—In order to meet the basic rule of thumb of 10 subjects for each variable entered into a multiple regression, it was necessary to reduce slightly the number of measures used in several instances. From the set of 17 perinatal and infant status variables, we omitted the two measures of night awakenings, since the N for these variables was substantially smaller than for other measures. From among the child outcome variables, we omitted the measures of accidents and illnesses at 12, 24, 36, and 48 months. As is clear from table 4, these measures have only the most modest relationship to any of the outcomes. Exclusion of these eight variables reduces the number of child outcome measures in the multiple regression to 12. Since we are primarily interested in prediction, we have also omitted from the analyses all concurrent measures in every cluster.

The results of the regression analyses for the four clusters of variables are given in table 5. Not surprisingly, in view of the correlation patterns evident in table 4, the predictions from the perinatal and infant status measures were extremely weak. In contrast, moderate to substantial multiple correlations were found for all three other clusters of variables. Of the three clusters, the ecological/perceptual variables appeared to be somewhat weaker predictors, although that was not the case for prediction of receptive language. The findings indicate that within this relatively healthy, well-developing sample of children, we can predict between 20% and 50% of the variance in IQ or language skill by measuring any of three things: the child's earlier test performance, the mother-infant interaction and environmental quality, or the mother's education and the support available to her within the family. Note that in the

TABLE 4

SIGNIFICANT CORRELATIONS BETWEEN PREDICTOR VARIABLES IN SEVERAL CATEGORIES AND 48-MONTH BINET IQ, AND 36-MONTH RECEPTIVE AND EXPRESSIVE LANGUAGE SCORES[a]

VARIABLE	AGE OF ASSESSMENT (months)	CORRELATION WITH BINET IQ	N	Receptive Language	N	Expressive Language	N
		Perinatal and Infant Status Variables					
Perinatal risk score	Perinatal/ Newborn	−.10	163	−.20**	164	−.22**	165
		Child Outcome Variables					
Bayley MDI	(12)	.21**	156	.28***	156	.13	157
Bayley MDI	(24)	.53***	149	.51***	149	.30***	150
Receptive language (SICD)	(12)	.28***	154	.16*	153	.12	141
Receptive language (BSID)	(24)	.45***	159	.50***	149	.35***	150
Receptive language (SICD)	(36)	.62***	149	...	...	.44***	164
Expressive language (SICD)	(12)	.21**	154	.09	153	.21**	154
Expressive language (BSID)	(24)	.53***	149	.46***	149	.46***	150
Expressive language (SICD)	(36)	.44***	150	.44***	164	...	...
Problem behavior (PBQ)	(36)	−.20*	159	−.28***	163	−.21**	163
Problem behavior (PBQ)	(48)	−.23**	159	...	...	...	...
Medically attended accidents	(12)	−.05	149	−.17*	147	−.11	174
Total illnesses	(12)	−.06	149	−.23**	147	−.09	148
		Ecological and Parent Perception Variables					
Neonatal Perception Inventory	Newborn	−.29***	158	−.19*	161	−.07	162
Developmental expectations	Perinatal/ Newborn	−.22**	150	−.35***	149	−.10	149
Social support	Perinatal	.31***	156	.43***	155	.21**	156
Positive pregnancy	Perinatal	.02	156	.17*	155	.06	156
Mother's education	Perinatal	.38***	163	.41***	163	.23**	164
Life change	Perinatal	−.09	156	−.25***	156	−.08	157
Life change	(4)	−.11	158	−.19*	159	−.15	160
Total HOME	(4)	.34***	147	.44***	158	.25**	159
Total HOME	(12)	.43***	153	.54***	154	.35***	155
Total HOME	(24)	.60***	133	.49***	132	.40***	133
Total HOME	(36)	.55***	150	.33***	163	.26***	164
Total HOME	(48)	.57***	153	...	...	...	...
Mother teaching score	(4)	.22**	157	.20**	158	.19*	159
Mother teaching score	(12)	.29***	145	.30***	147	.21*	148
Mother teaching score	(24)	.53***	144	.26**	145	.29***	146
Mother teaching score	(36)	.48***	151	.46***	164	.28***	164
Mother teaching score	(48)	.47***	155	...	...	...	...
Child teaching score	(12)	.17*	145	.17*	147	.12	148
Child teaching score	(24)	.26**	144	.23**	145	.12	146
Child teaching score	(36)	.21*	151	.07	164	.09	165
Child teaching score	(48)	.23**	155	...	...	...	...
Mother feeding score	(4)	.22**	137	.20*	139	.11	140
Mother feeding score	(12)	.12	134	.15	134	.20*	135
Child feeding score	(12)	.09	134	.17*	134	.25*	135

NOTE.—Figures shown in parentheses represent months.

[a] Only those variables on which at least one of the predictive correlations was significant at the .05 level or better are shown.

* $p < .05$.

* $p < .01$.

*** $p < .001$.

TABLE 5

Multiple Correlations Predicting Cognitive Outcomes from Four Clusters of Predictor Variables

Predictions of 48-Month Binet IQ				Predictions of 36-Month Receptive Language				Predictions of 36-Month Expressive Language			
Variable	*R*	Beta	*F* to enter	Variable	*R*	Beta	*F* to enter	Variable	*R*	Beta	*F* to enter
Perinatal and Infant Status Variables (15 Variables Entered)											
				Perinatal risk	.20	−.199	5.89*	Perinatal risk	.22	−.219	7.18**
				$F(1,142) = 5.89$*				$F(1,142) = 7.18$**			
Child Outcome Variables (12/8 Variables Entered)[a]											
Receptive language (36 months)	.62	.458	88.77**	MDI (24 months)	.51	.320	50.49**	Expressive language (24 months)	.46	.442	38.20**
Expressive language (24 months)	.68	.298	20.07**	Receptive language (24 months)	.55	.276	7.92**	Expressive language (12 months)	.49	.157	4.49*
Receptive language (12 months)	.70	.163	7.06**								
$F(3,140) = 44.34$**				$F(2,141) = 30.43$**				$F(2,141) = 21.82$**			
Ecological and Perceptual Variables (12/11 Variables Entered)[a]											
Mother's education	.38	.297	24.20**	Social support (perinatal)	.43	.312	33.14**	Mother's education	.23	.195	8.06**
Neonatal perception (newborn)	.45	−.250	11.06**	Mother's education	.54	.300	23.40**	Social support (perinatal)	.28	.168	4.33*
Social support (perinatal)	.51	.248	11.63**	Developmental expectations	.57	−.186	6.47*				
				Neonatal perception (perinatal)	.59	−.149	4.85*				
$F(3,145) = 17.08$**				$F(4,144) = 19.27$**				$F(2,146) = 6.29$**			
Mother-Infant Interaction and Environmental Quality Variables (16/13 Variables Entered)[a]											
Total HOME (24 months)	.60	.296	66.03**	Total HOME (12 months)	.54	.531	48.43**	Total HOME (24 months)	.40	.402	22.78**
Mother teaching score (24 months)	.66	.293	15.89**	Child teaching score (24 months)	.58	.204	7.23**				
Total HOME (36 months)	.69	.263	9.19**								
$F(3,116) = 35.26$**				$F(2,117) = 29.12$**				$F(1,118) = 22.78$**			

[a] The first number given is the number of variables entered for predictions of 48-month Binet IQ; the second, smaller number is the number of variables entered in predictions of 36-month language scores, from which all concurrent 36-month variables have been removed.

* $p < .05$.

** $p < .01$.

family ecology cluster, in every instance additional information about social support significantly improved the prediction that could be made from knowing the mother's years of education. Thus, it is not "social class" alone that is of importance, but rather the perceived supportive or stressful quality of the family interaction.

Comparing measurement points.—The second set of regression analyses is presented in table 6. Except for the cluster of perinatal variables, we have met the criteria of 10 subjects per variable in each analysis. We have bent the rule somewhat in the perinatal cluster, including 22 variables in this regression, so that both the perinatal status measures and the ecological/perceptual measures obtained at the same time could be included in a single analysis. For these analyses, night awakenings at 4 and 12 months, and illnesses and accidents at 12, 24, 36, and 48 months have been included.

Since what we measured is confounded to some extent with when we measured it—particularly during the perinatal period—it is not possible to sort these two factors out completely. But given the measures used, it is apparent in table 6 that the magnitude of the multiple correlation obtained during the perinatal period was as large or larger than the 4-month or 12-month predictions. The perinatal prediction was exceeded at 24 and 36 months for IQ and expressive language, and at 36 months for receptive language. That is, it is possible to gather information at the time of an infant's birth that will tell us as much about his later IQ or language as will either direct observations of parent-infant interaction or direct measures of the child's cognitive or language development during the first year. Note, however, that the information we must collect at the child's birth to achieve this prediction is not standard data about the child's physical status; rather what we must do is assess the demographic characteristics of the family, some aspects of family functioning such as social support, and the mother's perception of her newborn child.

A second point to be made about table 6 is that beginning at 12 months—the first point at which assessments of child outcomes were made—measures of parent-infant interaction or environmental quality and measures of child outcome combine to yield the maximum prediction of later performance, especially for IQ and receptive language predictions. Knowing both how the child is actually progressing, and something about the stimulative qualities of the environment in which that progress is occurring, appears to be better than knowing only one of these.

Random subsamples.—Since the results in both tables 5 and 6 could reflect idiosyncratic sample characteristics as well as replicable relationships, alternate subjects were assigned to random samples A and B with the provision that high- and low-education subjects would be evenly distributed in the two groups. Multiple regressions parallel to those in tables 5 and 6 were then computed for each random sample. While the results were not identical for the two subsamples and the total sample, the major conclusions are not altered: Predictions from perinatal status variables were poorer than for any other variable cluster for all outcomes, with both the child outcome and parent-infant interaction clusters about equally strong in predictive power. In the by-age regressions, measures of family ecology and parent perceptions were the best predictors at birth, with the HOME total score and measures of child language strong predictors at later measurement points.

Education Differences in Predictive Patterns

The final issue raised in the present series of analyses is whether the pattern of predictions was the same for mothers who differed in level of education. This question could be examined by generating separate multiple regressions for the high- and low-education subgroups. Such analyses might be of interest, but they are difficult to interpret. Just how different do the regression equations have to be before we could conclude that the predictive patterns are not the same? An alternative strategy is to examine the actual correlations between each predictor and outcome separately for the two education subgroups, and then test for the significance of the difference between each pair of correlations. Table 7 presents those variables for which significant differences were found between the correlations for high- versus low-education subgroups. Where the pair of correlations differed significantly for one of the three outcomes, we have presented the equivalent correlations for the other outcomes for comparison purposes.

The most obvious point to make about this table is that there are very few variables on which significant differences in correlations occurred. For predictions of IQ, only three out of 76 pairs of correlations differed significantly; for predictions of receptive language,

TABLE 6—Multiple Correlations Predicting Cognitive Outcomes from Variables Obtained at Six Separate Time Points

Predictions of 48-Month Binet IQ				Predictions of 36-Month Receptive Language				Predictions of 36-Month Expressive Language			
Variable	*R*	Beta	*F* to enter	Variable	*R*	Beta	*F* to enter	Variable	*R*	Beta	*F* to enter
Perinatal Variables (22 Variables Entered)											
Mother's education	.38	.294	23.38**	Social support (perinatal)	.43	.321	32.24**	Mother's education	.23	.204	7.90**
Neonatal perception (newborn)	.45	−.256	10.68**	Mother's education	.45	.312	22.76**	Perinatal risk	.30	−.194	5.84*
Social support (perinatal)	.51	.245	11.23**	Developmental expectations	.57	−.200	6.30*				
Sex[a]	.53	−.150	4.34*	Neonatal perception (newborn)	.59	−.147	4.72*				
				Birth weight	.61	−.136	3.95*				
$F(4,139) = 13.75$**				$F(5,139) = 16.10$**				$F(2,143) = 7.00$**			
4-Month Variables (8 Variables Entered)											
Total Home	.34	.335	15.33**	Total HOME	.44	.438	28.67**	Total HOME	.25	.245	7.75**
$F(1,121) = 15.33$*				$F(1,121) = 28.67$**				$F(1,121) = 7.75$**			
12-Month Variables (13 Variables Entered)											
Total HOME	.44	.440	23.63**	Total HOME	.44	.542	41.45**	Total HOME	.35	.278	9.19**
Receptive language	.52	.284	11.02**	Receptive language	.56	.168	4.12*				
$F(2,100) = 18.50$**				$F(2,100) = 23.43$**				$F(1,110) = 9.19$**			
24-Month Variables (10 Variables Entered)											
Total HOME	.60	.349	73.31**	Bayley MDI	.51	.228	46.23**	Expressive language	.46	.346	35.24**
Mother teaching score	.66	.263	17.66**	Total HOME	.57	.263	12.55**	Total HOME	.50	.230	6.90**
Expressive language	.69	.252	11.40**	Receptive language	.59	.207	4.14*				
$F(3,129) = 39.90$**				$F(3,128) = 22.85$**				$F(2,130) = 21.86$**			
36-Month Variables (10 Variables Entered)[b]											
Receptive language	.62	.368	90.65**	Total HOME	.64	.493	104.13**	Receptive language	.44	.441	35.48**
Total HOME	.65	.247	11.96**	Expressive language	.69	.232	15.49**				
Expressive language	.67	.224	13.07**	Mother teaching score	.70	.146	4.48*				
Child teaching score	.69	.185	7.07**								
$F(4,142) = 39.09$**				$F(3,145) = 45.82$**				$F(1,147) = 35.48$**			
48-Month Variables (10 Variables Entered)											
Total HOME	.57	.389	68.42**								
Receptive language	.67	.263	33.41**								
Motor development	.71	.236	18.32**								
Expressive language	.73	.151	5.43*								
$F(4,142) = 39.90$**											

[a] Sex is scored boys = 2, girls = 1, so a negative beta weight indicates girls have slightly higher IQs at 4.
[b] Only nine variables were entered into language predictions at 36 months.
* $p < .05$.
** $p < .01$.

TABLE 7

CORRELATIONS BETWEEN PREDICTOR VARIABLES AND OUTCOMES FOR HIGH- AND LOW-EDUCATION SUBGROUPS ON THOSE VARIABLES ON WHICH SIGNIFICANT DIFFERENCES BETWEEN THE MAGNITUDE OF CORRELATIONS FOR THE SUBGROUPS WERE OBTAINED

VARIABLE	CORRELATIONS PREDICTING IQ				CORRELATIONS PREDICTING RECEPTIVE LANGUAGE				CORRELATIONS PREDICTING EXPRESSIVE LANGUAGE			
	High Education	Low Education	t Difference in r	p	High Education	Low Education	t difference in r	p	High Education	Low Education	t difference in r	p
Developmental expectations	.01	−.37**	2.35	< .02	−.07	−.38**	1.83	< .10	.00	−.07	...	...
Social support (perinatal)	.11	.54***	2.93	< .01	.02	.63***	4.85	< .001	.04	.27*	...	...
Life change (12 months)	.09	−.21	1.79	< .10	.04	−.26*	1.84	< .10	−.04	−.09	...	...
Life change (36 months)	.07	−.41***	3.02	< .01	−.05	−.37***	2.11	< .05	−.04	−.11	...	...
Mother teaching score (36 months)	.34**	.49***	...	...	.21*	.50***	2.09	< .05	.29**	.17	...	...
Total HOME score (4 months)	.20*	.36**	...	...	.17	.46***	1.98	< .05	.15	.20	...	...
Total HOME score (12 months)	.31**	.46***	...	...	.27**	.59***	2.40	< .02	.31**	.34**	...	...
Night awakenings (12 months)	−.03	−.24	...	...	−.03	.07	...	...	.12	−.35*	2.06	< .05
Medically attended accidents (12 months)	−.01	−.30*	1.71	< .10	−.08	−.42***	2.14	< .05	.05	−.43***	2.97	< .01
Expressive language (24 months)	.54***	.44***	...	...	.39***	.42***	...	...	.63***	.25	2.85	< .01

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

six out of 65 comparisons were significant. Furthermore for the entire set of variables, the direction of the relationship between predictors and outcomes was virtually always the same for the high- and low-education subgroups. In the midst of this cross-education consistency, however, lies one interesting difference. Within the family ecology and parent perception cluster there are three measures (developmental expectations, social support, and life change) for which correlations were consistently stronger in the low-education sample than for the high-education sample. In fact, no single correlation among the 12 variables in this cluster and any of the three outcomes was significant within the high-education subgroup, while 15 out of the 36 correlations were significant for the low-education subgroup. The same pattern holds for 1- and 8-month life-change scores, which we examined to check for the consistency of this finding. None of the six correlations among 1- or 8-month life change and the three outcomes was significant for the high-education group; four of the six correlations were significant for the low-education group, and in all four cases the high/low-education correlations differed significantly. Thus, while for the study as a whole the pattern of relationship between predictors and outcomes is very similar for high- and low-education subgroups, for variables in the family ecology and parent perception cluster the relationships are consistently stronger in the low-education group.

Discussion

Results from the present study confirm the findings of others in a number of important respects, add to our knowledge in several other areas, and raise some puzzling questions which require further research.

Our findings support the broad conclusion reached by others concerning the usefulness of information about perinatal status: compared with information about the environment, measures of perinatal status are relatively unhelpful in predicting later child functioning. Obviously this conclusion should not be generalized to all samples. Other investigators, including Werner (Werner et al. 1967) and Broman (Broman et al. 1975), have found at least modest relationships between perinatal status variables and later IQ when the samples varied more in birth weight or initial physical risk. Their findings point to the importance of retaining measures of such risks in any screening program that involves a highly

heterogeneous population. In relatively healthy samples such as ours, however, the importance of perinatal data is clearly outweighed by information about family functioning or parent-infant interaction.

Our results also confirm the findings from the majority of longitudinal studies (reviewed by McCall [1979] among others) in showing that measures of the child's performance on standardized tests are of little value in long-term prediction until the child is about 24 months of age. For example, in the present study, the 12-month MDI and receptive and expressive language scores are only very modestly related to 48-month IQ ($r = .21$, .28, and .21, respectively) while the parallel correlations between 24-month scores and 48-month IQ are quite substantial ($r = .53$, .45, and .53, respectively). (All three of these 12- vs. 24-month comparisons are significant at $p < .10$; two are significant at $p < .01$.) This pattern of results is not consistent with recent findings from a somewhat parallel longitudinal study by Siegel (1981), who has found strong correlations (ranging from .45 to .60) between 12- and 24-month MDI, and between 12-month MDI and 24-month language scores. Of course Siegel is reporting links between two tests given only 12 months apart, which we might expect to be more strongly related than measures taken 24 or 36 months apart. But in the present study, 12- and 24-month MDI scores were correlated only .29 ($p < .01$), which is the same order of magnitude as the relationships we found between 12-month MDI and 48-month Binet IQ. The most logical explanation of the difference between Siegel's results and those reported here is that half of Siegel's subjects are preterm infants, many of whom are still performing poorly on the Bayley scales at both 12 and 24 months. For this group of physically high-risk infants, measures of mental or linguistic development during the first year of life may well be helpful predictors of later functioning; within a more normal group, the predictive utility of presently available standardized infant tests is greatly reduced. We do not mean to imply by this conclusion that no measures of infant functioning will be found to be related strongly to later cognitive performance. Two recent studies by Fagan and McGrath (1981) and Lewis and Brooks-Gunn (1981) suggest that measures of an infant's recognition memory or response to novelty in the first 6 months of life are notably better predictors of later IQ or language than are early Bayley scores. What does seem clear at present is that, except within such samples as the preterm group studied by Siegel, existing standardized tests do not provide helpful predictive information until the child is approximately 24 months old.

A third confirmation of previous findings lies in the general magnitude of the predictive relationships obtained. Both Bradley and Caldwell (1976a) and Ramey et al. (1979) reported multiple correlations in the range of .50–.65 between early environmental measures and later IQ, which are generally similar to the multiple correlations reported here. This comparability is particularly striking in view of the fact that the children in the present study were considerably healthier and performed better than the groups studied by other researchers. For example, in our sample the average Binet IQ at 48 months was 114, and only 10 children had IQs below 90. In contrast, the average 54-month Binet IQ was 103.9 for the Bradley and Caldwell sample, while the 36-month Binet averaged 80.6 for the high-risk control group in the Ramey et al. sample. The findings we have reported here suggest that measures of family ecology, environmental quality, and child status are as potent in predicting cognitive outcomes within a range of average, to above average, infant development as others have found them to be in groups in which the children performed more poorly.

Beyond these confirmations of existing evidence, the results from the present study appear to us to add to our collective knowledge in at least three ways. First, we have shown that a cluster of variables we have labeled "family ecology" predicts later IQ and language better than any other cluster of measures obtained in the first year of life, and about as well as measures obtained at 24 months. The mother's level of education is an important ingredient in this cluster of variables, but social support appears to be an equally potent predictor. This finding is of special interest in view of Cochran and Brassard's (1979) recent suggestion that there may be causal links between the adequacy of parental social networks and cognitive outcomes for the child. Results from the Minnesota longitudinal study of families at high risk for child abuse (Egeland & Sroufe 1981) provide further evidence for the importance of knowledge of social support and family life stresses in making predictions. In the Minnesota sample, those infants who showed secure attach-

ments despite generally inadequate care typically had mothers who had experienced low levels of life stress, or were raised in families in which there were supplemental sources of social support, such as a grandmother living with the family.

These findings should not be taken as evidence that the quality of the actual interaction between the mother and the child, or the general adequacy of the environment, are not important predictors. In our own data, at most ages the total HOME score was the single best predictor of IQ or language. But our results do suggest that a broader assessment of stresses on and supports within the family can add significantly to the magnitude of predictions.

Evidence that predictive equations are as good within educationally homogeneous groups as in more heterogeneous samples also adds significantly to existing information. In Aylward and Kenny's phrase (1979), the "risk routes" appear to be similar in high- and low-education groups in our own sample. The one notable exception to this general conclusion is the cluster of family ecology variables. Variables in this cluster are significantly related to later IQ or language only with the low-education group. Two possible explanations of this pattern occur to us. First, it is possible that we are dealing here largely with differences in variance between the two groups. For example, most of the fathers in the high-education group were present during the pregnancy and were strongly supportive of the mother. Among the low-education group there were a number of single mothers and others whose partners were less supportive. The fact that social support is predictive of IQ and language for the low-education group may, thus, be a simple reflection of the fact that only in that subgroup did the score vary widely.

An alternative explanation, however, is that there may be a different interactional dynamic operating in the high- and low-education families. For example, perhaps mothers with less education respond differently to high levels of life change or low levels of social support. These mothers may be less able to "buffer" the child against vicissitudes in their own personal relationships. A number of researchers studying the impact of life change on behavior have recently argued that adults do vary predictably in their ability to handle high levels of personal stress. Specifically, adults with better personal support systems and those with more education are thought to be better able to weather the inevitable episodes of high life change (Dohrenwend & Dohrenwend 1978; McFarland, Norman, Streiner, Roy, & Scott 1980). Clearly there is much yet to be learned about factors that influence individual skill in coping with stress (and a newborn infant in the family does create stress); our results are at least consistent with the hypothesis that one of the specific features of low-education families that increases the risk of later poor intellectual or linguistic performance for the infant is a lesser ability of the parents to adapt to the changing demands of the child, and to create or use helpful support systems for themselves.

The design of the present study permits us to answer still another question that has not been addressed by others, namely, when one should assess infants or families for maximum predictive efficacy. Actually this question has several variants. There is a comparative question: If one could choose any age at which to make observations, which age would be best? And there is a practical question: If one can only observe at time X because that is the time in real life when babies pass through a clinic or are seen by a public health nurse, what should be assessed? A complete answer to both of these questions would require that precisely the same variables be estimated at each of a series of ages. Such a design is not readily achieved, however, for various reasons, including the fact that assessment techniques do not presently exist to estimate all relevant variables at every age. For example, Brazelton assessments are done only with newborns, and the HOME Inventory is not normally used earlier than the child's sixth month (although we shifted it downward to 4 months in the present study). Because of such practical problems, and because we were unsuccessful in some instances in creating psychometrically adequate measures of important variables at every age, we do not have complete matching of variables at each data point. But we can come closer to a comparison of ages than is true for similar longitudinal studies. Within the limits of our data, several tentative conclusions seem reasonable: (1) If you can only assess families once, either birth or 24 months would be the best choices. (2) Quite different types of data should be collected, however, if you assess at birth versus 24 months. In the former case, information about family functioning and the parents' perception of the child appear to be most useful; in the latter case, measurement of the child's

performance on standardized tests combined with observation of the home environment would seem optimal. Whether information about the family ecology at 24 months would significantly add to the combined prediction we cannot say with our data, although we suspect that it would. (3) If circumstances require you to assess families between birth and 24 months, then observation of the general quality of the home environment will yield the most useful information. These conclusions must remain tentative because of the limitations imposed by the healthy sample we studied, the limited set of variables we assessed, and the lack of comparability of variables at each age. Nonetheless, the findings raise both theoretical and practical questions that should be addressed by others.

Any study of this size is certain to generate at least a few unexpected and puzzling findings. The present study is no exception. Perhaps most curious is the consistent pattern of stronger predictions of receptive than of expressive language. Differences in variance between the two scores cannot account for this pattern. The scores were converted to standard scores and the ranges were virtually identical (56–116 for receptive language; 54–117 for expressive language). Several other alternative explanations are possible, from which we cannot choose at this stage: (1) the SICD may measure receptive language with greater reliability than expressive language, or (2) receptive and expressive language may have somewhat different roots, and we simply sampled more fully from among the antecedent conditions for receptive language.

Equally unexpected are the findings concerning the Neonatal Perception Inventory (NPI) (Broussard 1976, 1980; Broussard & Hartner 1970), which in our sample are negatively related to later IQ. That is, mothers who thought their newborn infants were better than the average infants later had children with lower IQs. This is the opposite of what we had expected, given Broussard's data. In her studies, the 1-month NPI was positively related to better social/emotional development in the child. The only explanation of our findings that seems plausible at the moment is that some mothers may have unrealistically high expectations for their newborn's adaptability and specialness, and are then disillusioned when the baby turns out to wake up in the night and spit up and cry just like every other infant. If that were true, however, we might expect to find that the 1-month NPI—after reality had set in—would relate in the expected way with later performance by the child, but it does not. Clearly this is a finding that needs to be checked by others.

To summarize, results from the present study support the findings from comparable longitudinal studies in showing that measures of environmental quality and of parent-infant interaction taken in the first year of life are good predictors of later IQ or language performance. Perhaps most strikingly, our results show this conclusion to be valid within a relatively healthy, above-average sample, and to be equally true among high- or low-education mothers. Thus, the now oft-reported relationship between home environment and the child's IQ appears not to be an artifact of the mother's education, or of social class more broadly. Our results also show that assessments of the child's own mental development using standardized tests add appreciably to the prediction beginning at 24 months of life, but not before that age. These conclusions now seem well established, and require little further elaboration. What does seem to us to call for greater exploration is the role of such family ecological variables as social support or life change, and of such parent perception measures as developmental expectations. We are particularly impressed by the potency of these variables in light of the fact that our measurement strategies in this cluster were often quite primitive. The social support measure, for example, was created after the fact from replies to a series of questions during the maternal interviews. We did not set out originally to assess the mother's social support broadly. Similarly, the measure of life change we used has been found in subsequent research to be less helpful than are measures that yield separate scores for positive and negative changes, or than systems that require the respondent to indicate the degree of adaptation actually required by each change (Dohrenwend & Dohrenwend 1978; McFarlane et al. 1980; Mueller, Edwards, & Yarvis 1977). Development of better measures in both of these areas, as well as in the area of the parent's perception of the infant, would seem to be potentially highly fruitful. We have been pursuing this line in our current research.

The potency of the family ecology variables in predicting child outcomes also has important implications for intervention, as we have found in our own subsequent studies. We are convinced that in those medically high-risk families in which the mother lacks adequate social support and/or experiences high levels of disorganization in her life, intervention needs

to begin with the problem of social support. Providing such a mother with information about normal child development, or about how to stimulate her child appears to be of little use unless the mother's own life circumstances are addressed first. Our current work focuses on the problem of identification of those family ecology variables that will help us to match the family with the appropriate form of intervention. Most researchers in the past have been content to describe individual families and samples in terms of such standard measures as social class, ethnic composition, or parent education. Findings from the present study, and preliminary findings from our ongoing research, persuade us that far more detailed assessments of the mother's resources, and of the functioning of the family, are necessary both for good prediction and for appropriate intervention.

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