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ABSTRACT

The relationship of infant mental development (Bayley Mental Scale, eight months) to four year Binet IQ was explored in the context of the study sample's neurological and socioeconomic characteristics for a sample of 536 full-term children. The Minnesota sample was approximately normal or average in terms of infant mental scores, infant neurological status, socio-economic status, and four year IQ. SES showed the highest relationship to four year IQ (R for males of .43, females, .38) but infant mental score also showed meaningful correlation with four year IQ (R for males of .28, females .23). SES showed no correlation with infant mental scores. Categorical analysis showed that low mental score was a better predictor of low four year IQ (IQ less than 85) than was low SES. High SES was a better predictor of high four year IQ (IQ greater than 115) than was high mental score. (Author)

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FOOTNOTE

This is a report from University of Minnesota Section of the Collaborative Study of Cerebral Palsy, Mental Retardation and Other Neurological and Sensory Disorders of Infancy and Childhood. This study is supported by the National Institute of Neurological Diseases and Blindness (NIH Grant #PH -43-68-9). The following institutions participate: Boston Lying-In Hospital; Brown University; Charity Hospital, New Orleans; Children's Hospital of Buffalo; Children's Hospital of Philadelphia; Children's Medical Center, Boston; Columbia University; Johns Hopkins University; University of Minnesota; Medical College of Virginia; New York Medical College; Pennsylvania Hospital; University of Oregon; University of Tennessee; and the Perinatal Research Branch, NINDB. Harold Ireton's address: University of Minnesota Health Sciences Center, Hospital Box 393, Minneapolis, Minnesota 55455.

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INTRODUCTION

Early studies of mental development in normal infants demonstrated little or no relationship between mental ability in infancy and intelligence at a later age (Bayley, 1949). Subsequently, Knobloch and Pasamanick (1966), with a clinical sample of infants under age one year, obtained a multiple correlation of .84 between Gesell Developmental Quotient, medical data, socio-economic status and follow up Binet IQ (ages 6-10). Recently, Werner, et. al. (1968), demonstrated appreciable relationship between mental ability at 20 months and intelligence at age ten for a general sample of children in a longitudinal study. This study obtained a correlation between Cattell IQ at 20 months and intelligence at age ten (Primary Mental Abilities) of .49. Multiple correlation of Cattell IQ plus medical data plus socio-economic index with ten year IQ was .58. Most of the added predictive power was attributable to socio-economic status.

The present study focuses on the relationships between mental development and neurological status in infancy, family socio-economic status, and intelligence at age four. The particular focus is on the relationship between infant mental development and later intelligence in the context of the neurological and socio-economic characteristics of the population under study. This framework is based on the assumption that the apparent contradictions in the results of previous studies can be better understood by consideration of the neurological and socio-economic characteristics of the children and families under study.

The children and families studied are from the University of Minnesota Hospitals sample of the Collaborative Study on Cerebral Palsy, Mental Retardation, and Other Neurological and Sensory Disorders of Infancy and Childhood. Generally, the purpose of the Collaborative Study is to examine the relationships between pregnancy and outcomes of pregnancy. Mothers are enrolled in the study early in their pregnancies and the course of pregnancy, circumstances of delivery, and status of the newborn are documented. Family data including socio-economic data are obtained during pregnancy and subsequently. The children are followed for a period of eight years and examined at different ages by a variety of specialists including pediatricians, neurologists, psychologists, and speech-language-hearing specialists. Medical history data are also obtained during this period. The data of particular interest here are those pertinent to infant mental development and neurological status, family socio-economic status, and intelligence at age four.

PROCEDURE

The study group consisted of Minnesota sample children of term birthweight (birthweight greater than 2500 grams) for whom relevant data were available (N=536). The sample includes males and females in about equal numbers. The following data provide the basis for the analysis: Bayley Mental Scale score at eight months (7 months, 15 days - 9 months), neurological exam at 12 months (48-60 weeks), socio-economic status index obtained during pregnancy, and Binet IQ at four years (3 years 11 months - 4 years 3 months).

The Bayley Mental Scale (Perinatal Research Branch - Research Form) in the six to ten month range includes items involving sustained attention, manipulation of objects in a purposeful fashion, simple imitation and comprehension, simple vocalization and memory. While fine motor coordination plays a large part in many of these tasks, the items involve manipulation and comprehension beyond simple prehension.

The neurological examination is based on current functioning only, excluding historical data. The exam is performed by a neurologist or pediatrician who has been instructed in the use of the examination according to the project 12 month neurological examination manual. Specific findings are recorded on a structured printed protocol. The examiner also records his neurological diagnosis as (1) None, (2) Neurologically "Suspect" but no definite neurological abnormalities, or (3) Neurologically "Abnormal" child.

The SES Index, a ten point scale, is based on the average of education, income, and occupational ratings (Perinatal Research Branch Index, Myrianthropolous). The four year IQ is the Stanford-Binet, L-M, Short Form IQ. Each of these data were obtained independently.

RESULTS

Minnesota Sample parents, although almost exclusively white, are a fairly representative urban sample in terms of socio-economic status. According to Myrianthropolous, "Minnesota provides a surprisingly good fit when frequencies are compared with those for the urban population of the North Central States". Compared to the national average (Perinatal Research Branch Index: Average Range 5-5.9), the Minnesota Sample is at the high end of the

middle range (Mean PRB Index 5.9). There is no heavy concentration of low socio-economic status families in this sample.

The sample would be atypical in trms of the presence of a sizeable number of fathers who are students at the University of Minnesota and who score high on education and occupation but relatively low on income. Father's mean education level is 12.5 years; mothers 11.6 years. Consistent with the above, father's also show a greater range of educational achievement (Father's Standard Deviation - 3.36; Mother's Standard Deviation - 2.41).

Twelve month neurological data for the study sample of term births indicates that ninety-five percent (94.75%) are rated as neurologically within normal limits. There are only seven children rated as neurologically "Abnormal" (1.3%). Twenty-one cases are rated neurologically "Suspect" (4%). For the Collaborative Research Project Sample as a whole, which includes a broad socio-economic range, Drage, et. al. obtained a 1.9% incidence of neurological abnormality at 12 months. For term births only Drage obtained a 1.5% incidence of neurological abnormality. The present study sample appears to be characterized by a minimal incidence of neurological deviation at age 12 months.

Insert Table 1 about here

The psychological data for the children are presented in Table 1 which shows the means and standard deviations for the eight month Bayley Mental Scale Raw Score and four year Binet IQ for both sexes combined. Sex differences are not a particular focus of this study but will be commented on when relevant.

On the Bayley Mental Scale the mean raw score for both sexes (79.12) falls right at the midpoint of Bayley's 7-9 month interval. While conversion tables were not available, this mean raw score would equal a mean developmental quotient (DQ) of almost exactly 100. Females tended to score somewhat higher than males but the difference was less than one raw score point (.6). The Bayley Raw Score standard Deviation (5.15) places the raw score boundaries for ±1 SD at almost exactly the upper and lower boundaries of the Bayley 7-9 month interval. In other words about 66% of our sample of eight month olds functioned within the 7-9 month range according to Bayley's norms. The Minnesota eight month data provide a surprisingly good fit to the Bayley norms. Further, the score distributions are approximately normal. The overwhelming majority of individuals that fall below minus 1 SD (N=30) are functioning at no worse than a mildly retarded level (above age four months, less than 50% retarded). Only two cases are functioning at less than a five month level. These data suggest that we are dealing with a relatively normal population with a significant percentage of mildly retarded children but with very few more seriously retarded individuals.

Four year Binet IQ score ran somewhat higher for females than males (108 vs. 104). The combined mean IQ of 106 is somewhat above average in comparison to the Binet Standardization, but the standard deviation (16.27) is close to that expected for a normal sample. The high average mean Binet IQ is quite consistent with the high average socio-economic character of this sample.

The social, neurological, and psychological data to this point suggest the following: socio-economic status - fairly representative urban population, somewhat on the high side of average; neurological - infants with a relatively minimal incidence of neurological deficit; psychological - average infant mental development and high average four year intellectual functioning.

With this background data, we can turn to an analysis of the relationships of infant mental development, infant neurological status, and family socio-economic status to each other and to four year IQ. Correlation data are presented for term births only (94% of children) as the inclusion of premature infants would have necessitated a prematurity correction score for the eight month mental score.

Insert Table 2 about here

Table 2 presents the correlations between eight month mental score, 12 month neurological rating, socio-economic index, and four year IQ, separately for each sex. Consider first the correlations of infant mental score with infant neurological status and socio-economic status. Mental score shows a modest correlation with neurological rating for both sexes (.27). Mental scores shows no correlation with socio-economic status for either sex. Infant mental development is correlated with ratings of neurological status but not with family socio-economic status. Socio-economic status bears no relationship to mental development at this age for this sample.

Next consider the correlations of mental score, neurological rating, and SES index with four year IQ. For males, four year IQ is most highly correlated with socio-economic

status (.43), next with infant mental score (28), and least with neurological rating (.20). The order of correlation is the same for females although the correlations are of somewhat lesser magnitude (SES .38; mental score .23; neurological rating .11). The pattern of correlation for all these variables is very similar for both sexes. Infant mental development correlates with infant neurological status but not with family socio-economic status. Four year IQ correlates most highly with socio-economic status and least with infant neurological status.

The correlation of infant mental score with four year IQ indicates a modest but meaningful relationship between the two. Early mental development apparently has something to do with later intelligence beyond the near zero relationships reported in Bayley's early research.

The relatively high correlation of SES with IQ might lead one to conclude the SES is the best predictor of later intelligence. However, it is conceivable that for those infants of below average or accelerated mental development this is not so. Accordingly, IQ outcome was studied as a function of categories or levels defined for each of the predictor variables: mental score, neurological rating, and SES. Mental scores were categorized as Low (<-1 SD below mean), Average (within $\pm$ 1 P.E. of mean) and High ($>+1$ SD above mean). Neurological groups were "abnormal", "suspect" and "normal" as originally rated. SES groups were defined as Low (<-1 SD below mean), Middle (within ± 1SD of mean) and High ($>+1$ SD above mean).

Insert Table 3 about here

Table 3 presents the four year Binet IQ means and standard deviations plus the percentage of four year IQs less than 85 and greater than 115 for the total sample and by infant mental score, neurological and SES subgroup. These results are for both sexes combined. While females generally score a few points higher than males, the pattern of results is highly similar for both sexes. Recall that the distributions for the three predictor variables are all relatively normal or average. Differences between means were evaluated by t-test: differences between percentages were evaluated by X^2 test. Mental score subgroup four year IQ means differ significantly from each other (Low vs. Average, $p<.001$; Average vs. High, $p<.05$). The low group mean is only 90.70 which is about 16 points or one standard deviation below the population mean. The high group mean of 112.81 is only 6 points above the population mean. Considering percentage of below average and above average IQs, the low mental group shows a significantly greater percentage of IQs below 85 than the total sample (40% vs. 9%, $p<.01$) and a significantly lower percentage of IQs above 115 (3.3% vs. 24.3%, $p<.01$).The high mental group shows a significantly lower percentage of below average IQs than the general sample (0% vs. 9%, $p<.05$) but does not show a significantly greater percentage of above average IQs (30.2% vs. 24.3%, p NS). The average mental group closely parallels the total sample statistics. These results suggest that the greatest predictability for infant mental scores is in the low end of the mental score distribution, although a high mental score minimizes the likelihood of a below average IQ. Recall that this low mental score group was generally

only mildly retarded, not more seriously retarded.

Neurological subgroup outcome for "abnormals" can not be readily interpreted because of the small sample (N=7). They appear below average as a group ($\bar{X}$ 86.29) but extremely heterogeneous (SD 29.64). Neurological "suspects" mean IQ was significantly below that of the "normals" (97.14 vs. 106.17, $p<.05$). "Suspects" showed a significantly greater percentage of IQs below 85 than the total sample (28.6% vs. 9.0%, $p<.01$) and a significantly lower percentage of IQs above 115 (4.8% vs. 24.3%, $p<.05$). Those children rated neurologically "suspect" or "abnormal" at 12 months show a 28.6% chance of below average intelligence at age four.

SES subgroup IQ means differ significantly from each other (Low vs. Middle, $p<.001$; Middle vs. High, $p<.001$). The low and high SES means are about equi-distant from the middle SES mean, each falling about 9 points from the middle SES mean. The low SES group shows a significantly greater percentage of IQs below 85 than the total sample (22.5% vs. 9%, $p<.001$) and a significantly lower percentage of IQs above 115 (7.5% vs. 24.3%, $p<.001$). The high SES group shows a significantly lower percentage of below average IQs than the general sample (1% vs. 9%, $p<.01$) and a significantly greater percentage of above average IQs (43.1% vs. 24.3%, $p<.001$). The middle SES group closely parallels the total sample statistics. The group means and incidence of below average and above average IQs suggests that the SES variable is operative throughout its entire range in relation to four year IQ.

Comparing the relationships of infant mental score and SES to four year IQ suggests the following: (1) both correlate

with four year IQ, but SES shows a higher correlation, (2) the SES variable operates throughout its range; the mental score IQ relation derives primarily from the relationship between low mental score and below average later intelligence, (3) the low mental score - low IQ relationship can not be explained in terms of SES in that SES did not correlate with infant mental score, (4) low mental score tends to be a better predictor of below average intelligence than low SES (Low mental - 40% below IQ 85, Low SES - 22.5% below IQ 85, $p < .10$) at least for this sample, (5) high mental score or high SES is associated with a very minimal incidence of below average IQ (High mental - 0%, High SES - 1%).

DISCUSSION

The major assumption underlying this study was that the relationship between infant mental development and later IQ could only be understood in the context of knowledge of the neurological and socio-economic characteristics of the population under study. The present sample was not of adequate size to study these interactions directly. Willerman, et. al. (1969) demonstrated a large multiplier for the incidence of retardation for those children with low infant mental scores from low SES environments. The present relationship of infant mental score to four year IQ might be very different in a different sample. In terms of the correlation of SES with four year IQ one could easily conceive of a high SES sample in which this variable would mask or transcend the contribution of infant mental score. The negative findings of Bayley are consistent with this interpretation. The findings of the strongest relationship between low mental score and low IQ is consistent with the positive findings

of Knobloch and Pasamanick who sampled heavily from a deviant, below average population. A high frequency of neurological deficit in such developmentally below average infants would perhaps serve to maintain them in their subnormal status.

The demonstrated relationship between infant mental score and four year IQ is based on children who are literally infants in that an eight month old is a preverbal organism who manifests intelligent behavior primarily in his sensori-motor adaptations to his environment. It is naive to expect measures of sensori-motor adaptation in infancy to be highly predictive of later intelligent behavior with all its complexity, symbolic character, and multiple determinants. However, the present results are consistent with the statements of Piaget and Bruner who suggest that certain behavioral phenomena of infancy are manifestations of intelligent behavior in that they represent the child's attempts to operate on his environment in meaningful ways, and that such operations provide analogues to later intelligent behavior and are meaningfully related to such behavior. What is needed is a model that encompasses the child's early accomplishment (infant mental score) in the context of his biological-neurological status (birthweight, infant neurological, etc.) and environmental opportunities (SES, parents education, etc.). The Collaborative Project, with its diverse populations and sample of 50,000 children, may provide the data for the construction of such an interaction model.

TABLE 1

MEANS AND STANDARD DEVIATIONS OF 8-MONTH BAYLEY MENTAL SCALE RAW SCORE AND 4-YEAR BINET IQ FOR BOTH SEXES COMBINED

N=536

	$\bar{X}$	SD
8-Month Bayley Mental Score	79.12 (DQ≈100)	5.15
4-Year Binet IQ	106.10	16.27

TABLE 2

CORRELATIONS BETWEEN EIGHT MONTH MENTAL SCORE, TWELVE MONTH NEUROLOGICAL RATING, SOCIO-ECONOMIC INDEX, AND FOUR YEAR BINET IQ[1]
Ns (226-274)

	MALES			FEMALES		
	12 Neuro	SES	IQ	12 Neuro	SES	IQ
8-Mental	.27***	.10 NS	.28***	.27***	.02 NS	.23***
12-Neuro		.03 NS	.20**		.02 NS	.11*
SES			.43***			.38***

[1] Pearson product - Moment correlation - Significance levels:

*** $p < .001$

** $p < .01$

* $p < .05$

NS Not Significant

TABLE 3

FOUR YEAR BINET IQ MEANS, STANDARD DEVIATIONS AND PERCENTAGE OF IQs LESS THAN 85 AND GREATER THAN 115 FOR THE TOTAL SAMPLE AND BY INFANT MENTAL SCORE, NEUROLOGICAL, AND SES SUBGROUPS.

		N	$\bar{X}$	SD	% IQ<85	% IQ>115
Total Sample		536	106.10	16.27	9.0	24.3
Mental Score -	Low	30	90.70	19.30	40.0	3.3
	Average	282	106.97	15.53	8.5	27.3
	High	43	112.81	14.85	0.0	30.2
Neuro Rating -	Abnormal	7	86.29	29.64	28.6	28.6
	Suspect	21	97.14	13.69	28.6	4.8
	Normal	506	106.17	16.33	9.3	24.5
SES Index -	Low	80	97.45	14.62	22.5	7.5
	Middle	305	106.09	15.65	8.5	24.9
	High	102	115.37	15.19	1.0	43.1

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These results suggest that the greatest predictability for infant mental scores is in the low end of the mental score distribution, although a high mental score minimizes the likelihood of a below average IQ. Recall that this low mental score group was generally