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Nutrition and Mental Development in Children

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1. Introduction

Over the past two decades a number of investigators have addressed the question of whether childhood malnutrition causes retardation in mental development. To date, an unequivocal answer has not been forthcoming. This is understandable because of the many problems involved in designing an appropriate study to demonstrate causality.

Among these problems is the fact that the definition and measurement of nutritional status are still debated. Furthermore, the usual research strategies are difficult to apply to the study of the effects of malnutrition, since one can neither cause malnutrition in order to observe its effects, nor erase the poverty, illness, and social deprivation which coexist with malnutrition and constitute plausible alternative explanations of deficient mental development.

Malnutrition is not an easy concept to operationalize because, while it refers in part to input, or the food a person eats, the only measures usually available are output measures (i.e., growth or health status). Thus, the criteria for classification (summarized in Jelliffe, 1966) are all inferential, with past malnutrition inferred from present physical state. In particular, protein–calorie malnutrition (PCM) has been defined using indicators of physical growth, various clinical signs, and biochemical indicators.

The primary indicator of malnutrition is low weight for age, and the severely malnourished child has less than 70% of the expected weight for age (below the 30th percentile). The moderately malnourished child is usually

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identified by a growth retardation of less than 90% of the normal weight for age. The low weight for age of the moderately malnourished child may be accompanied by biochemical indications and/or evidence of reduced food intake, but almost never by clinical signs.

The majority of studies on human malnutrition and mental development have dealt exclusively with the effects of severe malnutrition (Birch *et al.*, 1971; Botha-Antoun *et al.*, 1968; Brockman and Ricciuti, 1971; Cabak and Najdanvic, 1965; Champankan *et al.*, 1968; Chase and Martin, 1970; Cravioto and DeLicardie, 1968; Cravioto and Robles, 1965; Cravioto *et al.*, 1966; DeLicardie and Cravioto, 1974; Edwards and Craddock, 1973; Evans *et al.*, 1971; Hertzig *et al.*, 1972; Liang *et al.*, 1967; Mönckeberg, 1968; Montelli *et al.*, 1974; Pollitt and Granoff, 1967; Stein *et al.*, 1972a). Typically, subjects have been children hospitalized for one of two forms of acute malnutrition, marasmus or kwashiorkor (Birch *et al.*, 1971; Brockman and Ricciuti, 1971; Cabak and Najdanvic, 1965; Champankan *et al.*, 1968; Chase and Martin, 1970; Cravioto and Robles, 1965; DeLicardie and Cravioto, 1974; Evans *et al.*, 1971; Hertzig *et al.*, 1972; Mönckeberg, 1968; Montelli *et al.*, 1974; Pollitt and Granoff, 1967). In these studies of severe malnutrition an association between early PCM and later poor cognitive performance has usually been found. However it is likely that the trauma associated with having a serious illness, being hospitalized, and being separated from the home environment in itself has negative effects on mental development.

Fewer investigations have focused on the consequences of mild-to-moderate malnutrition, although the number of children affected is far greater. In Guatemala, for instance, a recent report estimated that 80% of the country's children were undernourished, compared to a prevalence of severe malnutrition of 3% (INCAP/HEW, 1972). The effects of mild-to-moderate PCM have been studied by Boutourline *et al.* (1973), Chávez *et al.* (1974), McKay *et al.* (1969), Montelli *et al.* (1974), Mora *et al.* (1974), and Patel (1974). Like the research work on severe PCM cited, these studies have typically reported an association between malnutrition and poor cognitive performance, although causality has not been clearly demonstrated.

Up to the present, it has not been possible to establish a causal link between malnutrition and deficient mental development, largely because most studies have employed observational designs in which naturally occurring malnutrition has been identified and correlated mental development has been measured rather than experimental designs. Although most of these studies have found associations between early malnutrition and deficient mental development, an alternative causal explanation for these findings has always existed. Poverty and accompanying social deprivation almost invariably coexist with malnutrition (e.g., Chase and Martin, 1970; Chávez *et al.*, 1974; Cravioto and Robles, 1965; Evans *et al.*, 1971; Mönckeberg *et al.*, 1972; Mora *et al.*, 1974; Patel, 1974; Schlenker *et al.*, 1968; Stoch and Smythe, 1963, 1967). Since social deprivation may well play a causal role in deficient mental development (e.g., Hess *et al.*, 1968; Whiteman and Deutsch, 1968), the effects of nutritional and social variables on mental development are confounded.

One useful strategy employed in malnutrition/mental development research has been to identify situations in which the usual association between malnutrition and poor social and economic background does not hold. Winick *et al.* (1975) compared Korean infants with varying histories of malnutrition adopted by U.S. middle-class families and found that a good environment could substantially increase a previously malnourished child's chances for adequate development. Lloyd-Still *et al.* (1974) identified 41 middle-class children who had suffered severe malnutrition in the first 6 months of life as a result of cystic fibrosis or various congenital defects. These children showed mental deficits compared to siblings only at age 5. For older children differences were not present. Richardson (1976) studied 71 Jamaican schoolboys with a history of early severe malnutrition. Only the children who had inadequate growth and a poor social background after their episode of malnutrition continued to be retarded in comparison with siblings, whereas those with either adequate growth or a good home environment did not continue to show retarded development. These three studies suggest an independent causal role of malnutrition, and underline the important role of social environment for mental development, particularly in later childhood.

A second design solution to the problem of establishing causality consists of introducing experimental manipulation in the form of improvement of baseline nutritional status of a study population, along with prospective measurement of both nutritional status and social deprivation data. Because it involves prospective measurement of nutritional status, and because of the greater precision of measurement made possible by experimental manipulation, such a design is probably optimal. This design has been employed in the INCAP longitudinal study described in the present chapter.

2. The INCAP Study

Since 1969 INCAP has been collecting data on pregnant and lactating mothers and children from birth to 7 years of age in a longitudinal quasi-experimental intervention study. Four villages in the eastern, Spanish-speaking section of Guatemala, where malnutrition is endemic, were matched according to a number of demographic, social, and economic characteristics. The experimental intervention was differential supplemental feeding of two matched groups; two "experimental" villages were selected at random, where a high-protein/calorie drink similar to a popular corn-based gruel (atole) was made available twice daily for all residents at a central dispensary; and two were selected as "control" villages, where a drink was made available to all who wished to partake; this drink (fresco), similar to Kool-Aid, contains about one-third of the calories of the atole. Both drinks provide enough iron, vitamins, and minerals to ensure that none of these substances should be limiting in the recipients' diets. In both experimental and control villages, free outpatient medical care has also been provided since the inception of the study.

The study design is longitudinal, and as of 1969 all children in the villages from birth through 7 years of age have been measured in terms of the independent and dependent variables. Our primary concern in this chapter is the preschool children for whom we have information on supplemental food ingested by mother or child since the child's conception. The design is prospective in that data about a child's health and feeding are collected along with mental testing.

This design permits the examination of change over time from one testing to another, and thus makes possible investigation of whether supplemental feeding during a certain period is related to increases in test performance during the same period, or at what stage of mental development the largest effects of the supplemental feeding are likely to appear. It also permits determination of whether there are periods in development during which nutritional supplementation most affects subsequent mental development. Finally, the longitudinal design allows one to ask whether effects seen at one age persist to later ages or are erased by intervening circumstances.

2.1. *Definition of the Independent Variable*

The optimal measure of nutritional status is total nutrient ingestion by the mother during pregnancy and lactation and by the child up to the point of his mental testing. This measure would be the sum of supplemental feeding and level of home diet of the mother and child during these periods. Individually reliable home diet information is extremely difficult to obtain because of vagaries and biases of individual reporting, variability in what a child eats from day to day, and changes in the biochemical and nutrient composition of various foods from year to year. In fact, in the INCAP study, estimates of the total home diet based on dietary surveys are less precise than supplemental food ingested, which can be measured very accurately. Supplement ingestion has consistently been related to growth in the study population, and does not significantly replace home dietary consumption (Martorell *et al.*, 1978). We have, however, continued to measure home diet, employing it as a family background variable that assures us that high- and low-supplement ingestion groups do not differ in their family home diet.

2.2. *Measurement of Mental Development*

Measurement of preschool mental development in the longitudinal study has been purposely broad and eclectic. At 3, 4, 5, 6, and 7 years of age, the INCAP Preschool Battery (DDH/INCAP, 1975) is administered. It consists of 10 tests at ages 3 and 4, and 22 tests from age 5 on. The tests in the battery were selected to represent diverse theoretical orientations (e.g., learning, psychometric, and Piagetian), and to broadly sample attentional, perceptual analytic, learning, memory, and reasoning processes.

Reliabilities of Preschool Battery tests have been assessed, and are generally high. Interobserver reliability is at least 0.99 for each test. Test–retest reliability (1-week intervals) coefficients are also acceptable high (DDH Progress Report, 1975).

A major concern of the longitudinal study has been to assure that mental tests employed possessed emic validity (Berry, 1969; Irwin *et al.*, 1977), or were really measuring significant aspects of intellectual competence in the rural Guatemalan context. From the inception of the study, considerable effort has gone into achieving this objective. The tests in the Preschool Battery were adapted to the research setting by a team consisting of American and Guatemalan psychologists, a Guatemalan cultural anthropologist, and Guatemalan testers and cultural informants. Two years of pretesting, during which some tests went through as many as 10 revisions, were devoted to developing test materials and instructions which both the intuitions of the testers and the performances of local (pilot sample) children of various ages suggested were appropriate and meaningful.

Attempts to establish the emic validity of these measures have been made with subsamples of the longitudinal study population. In one such study, adults' ratings of smartness (Klein *et al.*, 1976; Nerlove *et al.*, 1974), which is translated as "listura" in Spanish and is associated with the concept of alertness, verbal facility, good memory, and a high level of physical activity, were correlated with a representative set of Preschool Battery tests (Vocabulary Recognition, Verbal Inferences, Discrimination Learning, Memory for Digits, and Embedded Figures) and found to be strongly related (r's up to 0.75) to these Preschool Battery test scores.

A second study has compared the school attendance and performance of children who received high and low scores on our Preschool Battery, and found consistent relationships between Preschool Battery scores and the age at which a child was first sent to school (higher-scoring children tending to be sent at younger ages), how long they remained (higher-scoring children tending to attend longer), number of years of school passed, and scores on nationally standardized achievement tests (Irwin *et al.*, 1978).

3. Results

3.1. Nutritional Status and Mental Development

The central question in the longitudinal study is whether mild-to-moderate malnutrition, a condition affecting the majority of children growing up today in developing countries, affects the mental development of these children. Our data argue strongly that the answer is yes.

Children in the sample were categorized as adequately, inadequately, and moderately supplemented from conception (DDH/INCAP, 1975). Mean psychological test scores at ages 3, 4, and 5 years for each supplementation category, and F values from a one-way analysis of variance by supplement category are presented in Tables I, II, and III. Since sex differences in test

Table I. Means, Pooled Standard Deviations, and Analysis-of-Variance F Values of Psychological Test Scores at 36 Months for Children Falling into Various Cumulative Supplementation Categories[a]

	1	2	3	S.D.	F^b
Composite Score	−0.41 (452)	0.60 (119)	0.78 (147)	3.64	8.09**
Embedded Figures	9.78 (440)	9.94 (119)	10.12 (144)	3.32	0.60
Digit Memory	10.19 (367)	12.42 (107)	11.96 (129)	8.23	4.28**
Sentence Memory	12.67 (385)	15.05 (108)	15.87 (134)	12.85	3.78*
Vocabulary Naming	6.66 (426)	8.28 (114)	8.04 (143)	4.18	10.52**
Vocabulary Recognition	19.90 (426)	20.98 (114)	20.66 (143)	5.72	2.11
Verbal Inferences	1.38 (191)	1.87 (53)	2.06 (50)	1.27	7.63**
Memory for Objects	1.94 (199)	1.95 (83)	2.19 (114)	1.39	1.32
Reversal Discrimination Learning	23.79 (393)	25.70 (115)	24.18 (137)	20.61	0.38
Knox Cubes	0.62 (88)	0.41 (46)	0.69 (62)	1.30	0.65
Draw-a-Line Slowly	10.22 (412)	9.57 (113)	8.90 (147)	4.44	5.09**
Persistence on an Impossible Puzzle	5.91 (364)	7.03 (116)	6.51 (148)	5.34	2.15

[a] Caloric supplementation per 3-month period: category 1 (≤ 5000 cal); category 2 (5000–9999 cal); category 3 (≥ 10,000 cal).
[b] Symbol: $*p < 0.05$; $**p < 0.01$.

performance were few, data for boys and girls have been combined. A composite score constructed by standardizing and then summing test scores, as well as several individual tests, show significant effects of nutritional status at each age. Tests which show the effects of food supplementation cover a wide

Table II. Means, Pooled Standard Deviations, and Analysis-of-Variance F Values of Psychological Test Scores at 48 Months for Children Falling into Various Cumulative Supplementation Categories[a]

	1	2	3	S.D.	F[b]
Composite Score	−0.41 (473)	0.59 (132)	0.98 (120)	3.87	8.21**
Embedded Figures	2.71 (451)	2.74 (129)	3.24 (119)	1.80	4.31**
Digit Memory	21.56 (448)	22.18 (128)	21.65 (115)	11.90	0.14
Sentence Memory	31.94 (442)	33.91 (128)	37.33 (113)	20.04	3.37*
Vocabulary Naming	12.11 (461)	13.95 (130)	14.49 (118)	5.13	14.36**
Vocabulary Recognition	25.70 (461)	27.79 (130)	27.39 (118)	5.34	10.65**
Verbal Inferences	2.92 (364)	3.19 (110)	3.22 (91)	1.49	2.41
Memory for Objects	3.63 (221)	3.80 (91)	3.68 (105)	1.68	0.32
Reversal Discrimination Learning	35.52 (458)	39.00 (131)	40.80 (118)	19.62	4.24**
Knox Cubes	1.36 (163)	1.75 (83)	1.22 (82)	2.02	1.57
Draw-a-Line Slowly	6.88 (449)	6.36 (129)	4.69 (120)	4.07	14.18**
Persistence on an Impossible Puzzle	8.88 (127)	9.78 (127)	10.01 (120)	6.46	1.89

[a] Caloric supplementation per 3-month period: category 1 (< 5000 cal); category 2 (5000–9999 cal); category 3 (> 10,000 cal).
[b] Symbols: $*p < 0.05$; $**p < 0.01$.

Table III. Means, Pooled Standard Deviations, and Analysis-of-Variance F Values of Psychological Test Scores at 60 Months for Children Falling into Various Cumulative Supplementation Categories[a]

	1	2	3	S.D.	F[b]
Composite Score	−0.70 (452)	0.87 (135)	1.90 (104)	7.64	6.05**
Embedded Figures	4.12 (450)	4.40 (135)	4.84 (103)	2.21	4.72**
Digit Memory	35.82 (441)	35.20 (135)	34.09 (103)	13.10	0.75
Sentence Memory	51.27 (442)	51.56 (134)	52.17 (104)	21.16	0.08
Vocabulary Naming	17.08 (449)	18.78 (135)	18.40 (104)	5.06	7.53**
Vocabulary Recognition	30.08 (449)	31.13 (135)	31.35 (104)	4.39	5.40**
Verbal Inferences	4.07 (422)	4.44 (128)	4.23 (99)	1.89	1.98
Memory for Objects	5.51 (197)	5.89 (88)	5.81 (88)	1.85	1.60
Reversal Discrimination Learning	23.73 (438)	25.56 (133)	29.68 (103)	21.20	3.37*
Knox Cubes	3.44 (202)	4.74 (88)	4.91 (89)	3.53	7.57**
Conservation of Material	0.29 (197)	0.34 (86)	0.26 (86)	0.60	0.40
Conservation of Area	0.35 (193)	0.40 (85)	0.38 (87)	0.67	0.16
Conservation of Continuous Quantity	0.20 (202)	0.21 (86)	0.17 (87)	0.43	0.17
Incomplete Figures	5.59 (203)	5.73 (86)	5.15 (84)	2.64	1.15
Elimination	5.10 (199)	5.24 (88)	5.33 (87)	2.16	0.40
Block Design	39.58 (202)	42.84 (88)	47.75 (88)	20.46	5.04**
Incidental Learning	1.34 (448)	1.77 (135)	1.79 (103)	1.27	9.36**
Intentional Learning	2.18 (448)	2.44 (135)	2.87 (103)	1.40	10.96**
Haptic-Visual	3.86 (351)	4.22 (126)	4.45 (103)	2.87	2.01
Face-Hands	2.44 (200)	2.37 (87)	2.42 (87)	1.39	0.09
Matching Familiar Figures	2.75 (443)	2.85 (134)	2.86 (103)	1.35	0.51
Memory for Designs	11.66 (444)	13.04 (131)	14.76 (102)	11.37	3.37*
Animal House	118.64 (196)	114.76 (88)	120.16 (87)	54.08	0.15
Draw-a-Line Slowly	4.42 (430)	3.39 (131)	3.18 (104)	3.13	10.27**
Persistence on an Impossible Puzzle	12.01 (365)	13.68 (130)	13.74 (102)	6.20	5.36**

[a] Caloric supplementation per 3-month period: category 1 (≤ 5000 cal); category 2 (5000–9999 cal); category 3 (≥ 10,000 cal).
[b] Symbols: $^*p < 0.05$; $^{**}p < 0.01$.

range of skills, including verbal reasoning, learning and memory, visual analysis, and motor control.

We have also attempted to determine if crucial periods exist in which nutritional status has a particularly strong impact upon subsequent mental test performance. To examine this question, we have employed regression analyses wherein supplementation during the distinct developmental epochs of pregnancy, 0 to 24 months, 24 to 36 months, and 36 to 48 months, was regressed on mental test performances at ages 3 and 4. These analyses could not be interpreted at age 5, since relatively few children tested as yet at age 5 have been well supplemented during pregnancy. However, at ages 3 and 4 these analyses suggest that supplementation during the periods of gestation and birth to 24 months is most important in determining mental development. Table IV presents simple slopes of supplementation on test performance during these

Table IV. Regressions on Test Performance Using a Caloric Supplement Varying by Time Periods

Test	N	Supplementation variable	Simple slope[a]	Partial slope[a,b]	S.D. of test score
		At 36 months			
Cognitive	718	*In utero*	0.218**	0.112	3.64
Composite		To child 0–24	0.126***	0.108***	
Vocabulary	683	*In utero*	0.212*	0.076	4.18
Naming		To child 0–24	0.150**	0.138***	
Verbal	294	*In utero*	0.223***	0.203***	1.26
Inferences		To child 0–24	0.051**	0.024	
		At 48 months			
Cognitive	725	*In utero*	0.281**	0.142***	3.87
Composite		To child 0–24	0.142***	0.122***	
Vocabulary	709	*In utero*	0.343**	0.093	5.12
Naming		To child 0–24	0.233***	0.220***	
Verbal	565	*In utero*	0.120**	0.096*	2.12
Inferences		To child 0–24	0.034*	0.020	

[a] Symbols: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[b] Partial slope of the supplement period indicated controlling for the other period

two periods, and partial slopes with each, after variance from the other period of supplementation was removed. These partial slopes indicate how much variance in test performance can be attributed to supplement during one period independent of the other. Data are presented for a reduced set of tests: the Composite Score, Vocabulary Naming, and Verbal Inferences. These last two tests were selected in addition to the Composite Score because data for Vocabulary typify effects seen at ages 3 and 4, while Verbal Inferences behaves uniquely, showing strong effects of early supplementation. All simple slopes for supplement both during pregnancy and from 0 to 24 months are significantly different from zero. In addition, the partial slopes of gestational supplementation controlling for supplement ingested from 0 to 24 months are significant for the Composite Score at 48 months and for Verbal Inferences at 36 and 48 months. In contrast, significant partial slopes for supplement ingestion from birth to 24 months controlling for gestational supplement are seen for the Composite Score and for Vocabulary Naming at 36 and 48 months. Although the partial effects vary somewhat by age and test, both periods of supplement appear to play an independent role in the mental development of these children at ages 3 and 4.

3.2. *Alternative Explanations for Findings, and the Roles of Social, Economic, and Biomedical Factors in Mental Development*

We have considered the possibility that nonnutritional variables may be confounded with and responsible for the apparent effects of supplementation on mental development observed in our analyses. Among the variables considered have been: effect of repeated testing, morbidity of S's, parental cooperation with the project, village differences, and attendance to the supplementation centers. Testing effects have been examined, and they do not appear to constitute a vaiable alternative explanation for our findings among 3- to 5-year-olds. The same may be said for child morbidity history and for parental cooperation with the project: correlations between morbidity measures and psychology scores are miniscule. So are correlations between parental cooperation ratings (made by staff personnel) and psychology scores.

We have also examined the possibility that the fresco and atole villages differ in characteristics other than treatment that might be related to mental development. These differences would confound the results, since well-supplemented children are more common in the atole villages, while nonsupplemented children are more common in the fresco villages. To explore village differences, an analysis of variance of year of project by village type (atole or fresco) was run on all 36-month psychology variables using only nonsupplemented children from the fresco and atole villages. Since none of these children have received much supplementation, any differences by type of village (atole or fresco) between them would support the existence of artifactual village differences. However, no main effect of village type above the 0.05 level was found for any test. Thus, village differences do not appear to constitute an alternative explanation for the observed supplement effects.

It is also possible that the social stimulation inherent in attending the supplementation center per se may increase test scores. Days of attendance at the supplementation center from 36 months on does appear to affect test performance byond that age. However, the magnitude of this attendance effect is quite small. Regression analyses examining the effect of number of days of attendance to our supplementation centers on Preschool Battery performance reveal that for every 100 days of attendance, an increment of 0.007 standard deviation unit on the Composite Score is produced. Thus, the size of this effect renders it of little importance as an alternative explanation of our previously observed effects of nutritional supplementation on test performance.

Another possible source of confounding secular change, or change over historial time, has been investigated. To address the problem of secular change, mean composite scores of the least supplemented children, who would have been relatively unaffected by the treatment, were calculated by year of the program. Inspection of the means has demonstrated that there is no linear trend over the duration of the program.

Probably the best candidate for an alternative explanation of our finding of an association between food supplementation and mental development is family socioeconomic status (SES). There are two important reasons for examining economic and social variables in our study. First, it is generally known that family characteristics are frequently associated with mental test performance (e.g., Whiteman and Deutsch, 1968; Hess, 1970), as was found in these villages. Second, family SES level usually covaries with children's nutritional status. Thus, family SES must be carefully measured in tested populations in studies of malnutrition and mental development to control for possible confounding effects.

The second reason for investigating the role of economic and social factors is that mental development almost certainly has multiple causes, and to understand the effects of nutrition on mental development we must first investigate interactions of nutritional status with other possibly causal variables. Thus, by employing measures of family SES level and intellectual stimulation in the home, we may be able to identify the conditions under which nutrition has its largest effects.

In the present study, family SES level is unrelated to supplement ingestion. This is not surprising, because the supplement is provided to all, regardless of their SES level. Furthermore, we know that the associations we have found between food supplementation and mental test performance are not due merely to SES differences between good and poor test performers; regression analyses in which successive offspring of the same mother are compared have been performed. Because these analyses make within-family comparisons, all family-level variables, including SES, are held constant. They indicate that mental test scores are significantly related to differences in nutritional status between successive offspring of the same mother, and that this within-family association is as strong as the between-family association of nutritional status and mental development described earlier. Although it does not explain the association between nutritional status and mental development, family SES level does appear to interact with nutritional status in affecting mental development. Although effects of supplement ingestion exist within both the upper and lower halves of the family SES distribution, these effects are somewhat different for children of low and high SES families.

A child's relative risk of falling into the lowest pentile of the Composite Score distribution if he is both low SES and inadequately supplemented is shown in Table V. The table presents the number of 3-, 4- and 5-year-old

Table V. Numbers of Children in Lowest Supplementation Category[a] during the Period from Birth to 24 Months Falling into the Lowest Pentile of Composite Score Performance or Not, by SES Level

	Lowest pentile	Higher pentile	Relative risk[b]
3 years			
Low SES	61	166	1.41*
High SES	47	200	
4 years			
Low SES	82	169	2.10**
High SES	43	233	
5 years			
Low SES	69	183	1.68**
High SES	47	241	

[a] Caloric supplementation per 3-month period category 1 (< 5000 cal); category 2 (5000–9999 cal); category 3 (> 10,000 cal).
[b] Symbols: $^{*}p < 0.05$; $^{**}p < 0.01$.

children in high and low pentiles of the Cognitive Composite distribution who fall into the lowest supplement category for the period of birth through 24 months as a function of family SES level. Low-SES children who were in the lowest supplementation category were at greater risk of being in the lowest pentile of test performance than were poorly supplemented children from higher SES families. This finding is more impressive because the range of family SES variation in the study communities is very small.

Family SES not only interacted with nutritional status to affect mental development, but also appears to have exerted an effect directly upon mental development. Table VI presents correlations between mental test performance and family economic indicators of House Quality and quality of Parents' Clothing, as well as with a number of family measures constructed to index aspects of intellectual stimulation available in the home, following to some degree Caldwell's Home Environment instrument (Bradley and Caldwell, 1976). These measures are: Mother Composite, which combines the mother's vocabulary test score, literacy, years of school passed, and modernity into a single index of intellectual characteristics; Father's Schooling, or his years of school passed; Sibling Schooling, or average years passed by all older siblings living at home; Toys, or the quantity and quality (e.g., presence of moving parts, etc.) of toys in the home; and Books and Objects, or the number of books, magazines, and visually stimulating objects such as drawings, photographs, pictorial calendars, diplomas, and decorated furniture found in the home.

As Table VI indicates, the Mother Composite of Intellectual Characteristics and Sibling Schooling both correlated consistently with test performances for boys, although Mother Composite was unrelated to test performance for girls and Sibling Schooling only related significantly to performance at age 5. Father's Schooling was unrelated to test performances. Of the two measures of material stimulation, Books and Objects, but not Toys, also correlated with test performance, but only at age 5. The economic indicators of House Quality and Parents' Clothing related significantly to test performances of both boys and girls at 5 years of age, and Parents' Clothing also related to boys' test performances at ages 3 and 4, and to girls' performances at 5.

In summary, family economic level, as well as human and material sources of intellectual stimulation, appears to influence mental development in the study communities. Work is presently proceeding on the development of various additional economic and social variables measured at the family level.

4. *Discussion*

Findings of the INCAP study to date suggest that there is an effect of malnutrition of mental development at least up to 60 months of age (the oldest children we have been able to study fully longitudinally to date), that nutritional input is of greatest importance during gestation and the first 2 years of life, and that the effects of a poor socioeconomic environment exacerbate the

Table VI. Correlations between Various Family Variables Related to Intellectual Stimulation and of Family Wealth Indicators, and Composite Score on the Preschool Battery at Ages 3, 4, and 5

Age (years)	Mother Composite[a,b]		Father Schooling[b]		Sibling Schooling[b]		Toys		Books and Objects[b]		House Quality[b,c]		Parents' Clothing[b,c]	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
3	0.13*	0.02	0.02	0.10	0.14*	0.01	0.05	0.00	0.02	−0.02	0.05	0.03	0.16**	0.02
4	0.17**	0.06	0.09	−0.01	0.26**	0.00	0.00	0.01	0.04	−0.05	0.05	0.07	0.16**	0.10*
5	0.20**	0.12*	0.13*	0.12*	0.31**	0.22**	0.06	0.10	0.20**	0.23**	0.13*	0.20**	0.12**	0.15**

[a] Cell n's for Mother Composite, Father Schooling, Sibling Schooling, Toys, Books and Objects, all = 300.
[b] Symbols: $*p < 0.05$; $**p < 0.01$.
[c] Cell n's for House Quality and Parents' Clothing = 600.

effects of early malnutrition. Furthermore, these data suggest, more strongly than have those of any previous study, that the effects of malnutrition on mental development are causal.

Two major questions regarding the effects of malnutrition on mental development remain to be answered. The first question concerns the nature of the mechanism through which malnutrition affects mental development. Two main possibilities seem consistent with the INCAP findings. The first of these possible mechanisms is that of structural damage to the developing nervous system. The animal research work of Winick *et al.* (1972) and of others, which has identified various anatomical differences in the brains of lower animals subjected to severe malnutrition during periods of rapid CNS development, certainly supports such a possibility.

The child's relationship to his environment in the first 2 years may also play a role. As Piaget and Inhelder (1969) have argued, intellectual development is an interactive process in which the growing child must both act and be acted upon by the world around him in order to mature. One type of interaction that has been demonstrated to be particularly important in subsequent intellectual development is that between mother and child (e.g., Hess *et al.*, 1968). Chávez *et al.* (1975) and Graves (1976) have recently presented evidence that mother–child interaction patterns for malnourished children differ from those for well-nourished children. Thus, it is possible that deleterious effects of insufficient energy on the child's interactions with his mother or other sources of environmental stimulation may underlie the increasingly well documented effects of malnutrition on mental development. This issue is currently being explored at INCAP.

The second question concerns whether the effects seen in childhood normally last into adolescence and beyond, condemning victims of early malnutrition to poor school achievement and less than competent adulthood. The studies of Winick *et al.* (1975) with Korean orphans adopted by middle-class families, of Stein *et al.* (1972a,b, 1975) with offspring of pregnant World War II famine victims in Holland, and of Lloyd-Still *et al.* (1974) with middle-class children who suffered severe infant malnutrition due to cystic fibrosis or congenital defects of the gastrointestinal tract suggest that effects of early malnutrition on subsequent intellectual development may be ameliorated in later childhood by a comfortable and stimulating home environment. However, the vast majority of victims of childhood malnutrition have little hope of substantial improvement in their deprived environments. Whether our well-nourished children will continue to show the effects of early good nutrition on their intellectual competence can best be determined in a longitudinal prospective study. This question is currently under investigation by the INCAP research team in Guatemala.

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