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Cognitive Defects in the Development of Mental Illness

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Malnutrition and Mental Development: Some Longitudinal Perspectives

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INTRODUCTION

Stimulated by international concern with dramatic population growth, inadequate world food production and inequitable food distribution even within more developed countries, a proliferation of studies of the effects of childhood malnutrition on later physical and mental development has been published in the past 20 years. A number of these studies, in settings differing widely in culture and nutritional deficiency, report an association between severe protein-caloric malnutrition and cognitive development (Cabak & Najdanvic, 1965; Cravioto et al., 1966; Evans et al., 1971; Mönckeberg et al., 1972; and Stoch & Smythe, 1967).

Fewer studies have focused on less severe but much more common mild-to-moderate malnutrition. While only an estimated 3% of the world's children experience an episode of severe malnutrition during their first five years of life, it has been estimated that more than half of all children growing up in developing countries (Béhar, 1968), as well as varying but significant numbers of children in low income families in

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more developed countries, are malnourished to some degree (U.S. Department of Health, Education and Welfare, 1972). Like the studies of severe malnutrition cited, the studies of these children have related the effects of mild-to-moderate malnutrition to cognitive development (Boutourline-Young et al., 1973; Chávez et al., 1974; McKay et al., 1969; Montelli et al., 1974; Mora et al., 1974; Patel, 1974).

However, the presumed link between moderate malnutrition and mental development is challenged by the findings of numerous investigations of the role of children's social environment on their cognitive performance (e.g., Evans et al., 1971). Moreover, due to design considerations, poverty and its accompanying social deprivation are invariably confounded with the apparent impact of nutrition on mental development (Chase and Martin, 1970; Chávez et al., 1974; Stein et al., 1972; Whiteman and Deutsch, 1968).

The present paper reports preliminary results of an ongoing longitudinal intervention study on the effects of mild-to-moderate malnutrition on mental development during the preschool years. The hypothesis of an effect of mild-to-moderate malnutrition on mental development was tested through an intervention design; dietary supplements were provided on a voluntary basis to pregnant and lactating women and to children in order to test for associated changes in physical growth and mental development. In addition to the food supplementation program, medical care was provided free of charge to all residents of the study communities. The present study is believed to be the best controlled field nutrition intervention yet attempted. Moreover, its longitudinal design allows for repeated careful measurement of the child's nutritional status and social environment over time.

RESEARCH DESIGN

In the Institute of Nutrition of Central America and Panama (INCAP) investigation, four villages from a rural Spanish-speaking area of Guatemala where malnutrition is endemic were matched on a number of demographic, social and economic characteristics. The experimental intervention was the differential supplemental feeding of the four villages. Residents of two villages were randomly assigned to receive a high protein-caloric drink similar to a popular corn-based beverage (atole). This drink, containing 163 calories and 11 grams of protein per cup, was made available at a central dispensary for all residents. In the other two communities a refreshing cold drink (fresco), containing no protein and 59 calories per cup, was similarly made available. Both drinks contain enough vitamins and minerals to insure that none of these would be lacking in the diet of recipients.

Attendance to the supplementation center was voluntary and consequently a wide range of supplement intake is observed. A daily record of attendance and supplement intake is kept for each individual.

STUDY POPULATION

The study children are from a rural Spanish speaking population in which mild-to-moderate malnutrition and infectious diseases are endemic. At the start of the project, infant mortality was approximately 150 per 1,000 per year. Currently, it is about 50 deaths per 1,000 per year. Median family income is approximately $300 per year. Corn and beans are the principal staples of the home diet. The typical house is made of adobe and has no sanitary facilities.

Beginning in February 1969, data were collected on all children in the four villages under seven years of age, and until February 1973, all children born in the villages were added to the sample. Since February 1973, data collection has continued on the sample but no newborns have been added. A total of about 1550 children up to seven years of age have been tested since the study's inception. The fully longitudinal sample consists of 671 children who were born in the four villages from January, 1969 through February 1973. The size of any particular group for analytic purposes depends on the sample chosen, the focus of the analysis, and the date of summarization.

VARIABLES CONSIDERED

The project has collected an extensive body of data on children's health status and medical treatment, nutritional supplementation, home food consumption, physical growth, mental development and a large number of social and environmental variables. The intervention or independent variable in analyses to date has been expressed in terms of supplementary calories ingested by the mother during pregnancy and lactation and by the child from birth up to the point of mental testing. Although the original design was intended as a test of the influence of protein intake on development, supplement intake has been expressed in terms of calories because the home diet appears to be more limited in calories than in proteins. Nutritional supplementation has been found to not significantly replace home dietary intake, but results in a net increment of nutrients (Lechtig et al., 1975) and has correlated consistently with physical growth (DDH/INCAP, 1975).

The principal outcome variables discussed here are birthweight, physical growth, and mental development. Data on birthweight and physical growth were collected at birth and at quarterly intervals thereafter using standard anthropometric procedures. From three to seven years of age, all children in the study were tested on an extensive battery of psychological tests known as the INCAP Preschool Battery. The tests reflect an eclectic theoretical perspective on mental development (drawing from the learning theory, intelligence-testing, and Piagetian movements in contemporary psychology) and were adapted to the research setting by a team of North American and Latin psychologists (Klein et. al., 1969).

Because of the quasi-experimental nature of the design, other variables which might account for a nutrition-mental development association were also measured. With respect to the social environment and economic status of each study family, a stable index of family wealth and a measure of the extent of explicit teaching of preschoolers in the home has been obtained four times since 1967. In 1975, mother's education, modernity and vocabulary, the degree of father's involvement with his children, and the presence of toys, books and other potentially stimulating material objects in each family's home were also measured. Additional potentially confounding variables (i.e., children's morbidity, parental cooperation, and attendance at the supplementation center per se) were also measured and will be discussed in the context of the results.

RESULTS

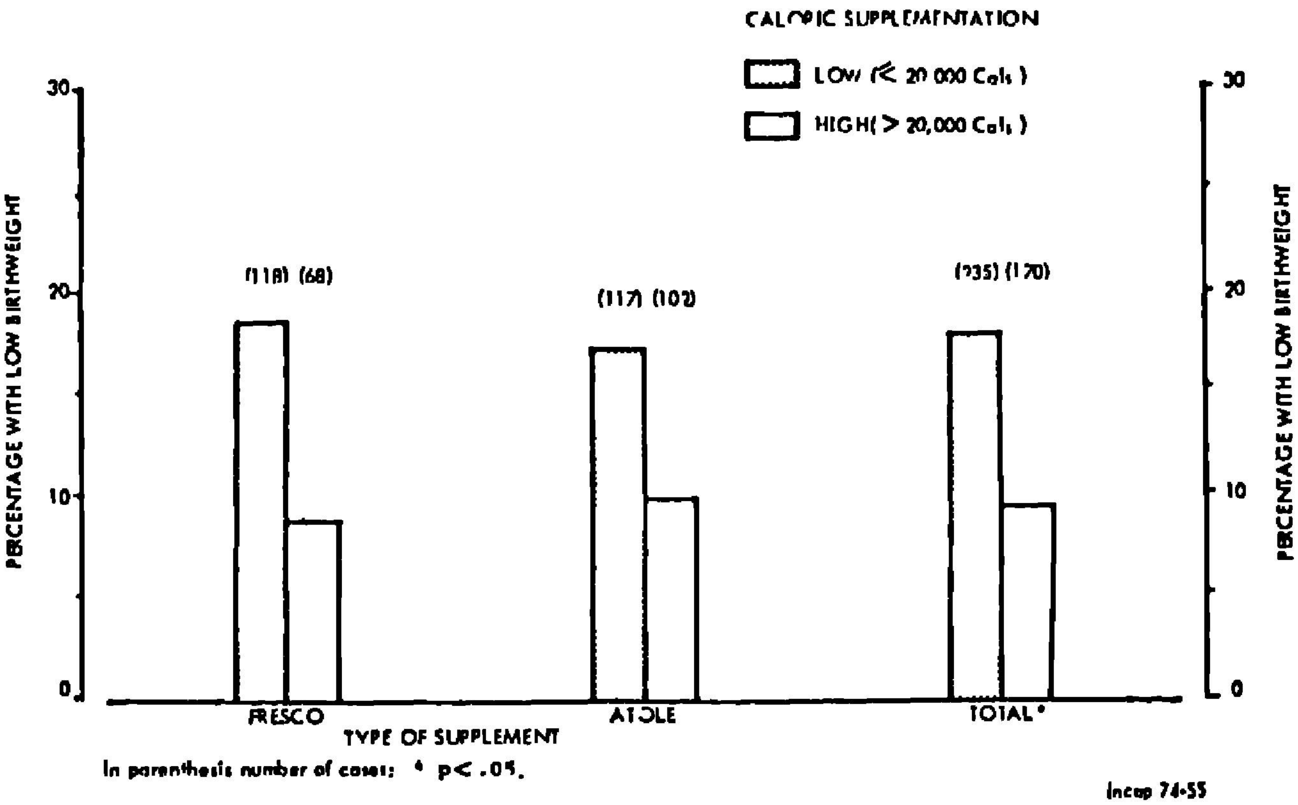
This section must be prefaced with the explanation that data collection has just been completed and thus the data which will be presented in this paper are in some cases incomplete. Even given the preliminary nature of our analyses, those results which are available are both interpretable and provocative. After reviewing the findings related to physical growth and psychological test performance we will discuss some implications of the results of the investigation.

Determinants of Physical Growth Retardation

Supplement Ingestion and Birthweight. Figure 1 shows the percentage of low birthweight babies ($\leq$ 2.5 kg) by two categories of maternal supplement ingestion. The low group is comprised of women whose total supplement ingestion during pregnancy was less than 20,000 calories, while the high group consists of mothers whose supplement ingestion was greater than 20,000 calories. The percentage of low birthweight babies is consistently lower in the better supplemented group in both the fresco and the atole villages. In fact, the risk of delivering low birthweight babies among highly supplemented mothers is roughly half that in the low group. Since home caloric intake was similar in both groups, the supplemental calories represent additional calories to the maternal diet.

FIGURE 1

Relationship Between Supplemented Calories During Pregnancy and Proportion of Low Birthweight (≤ 2.5 kg)



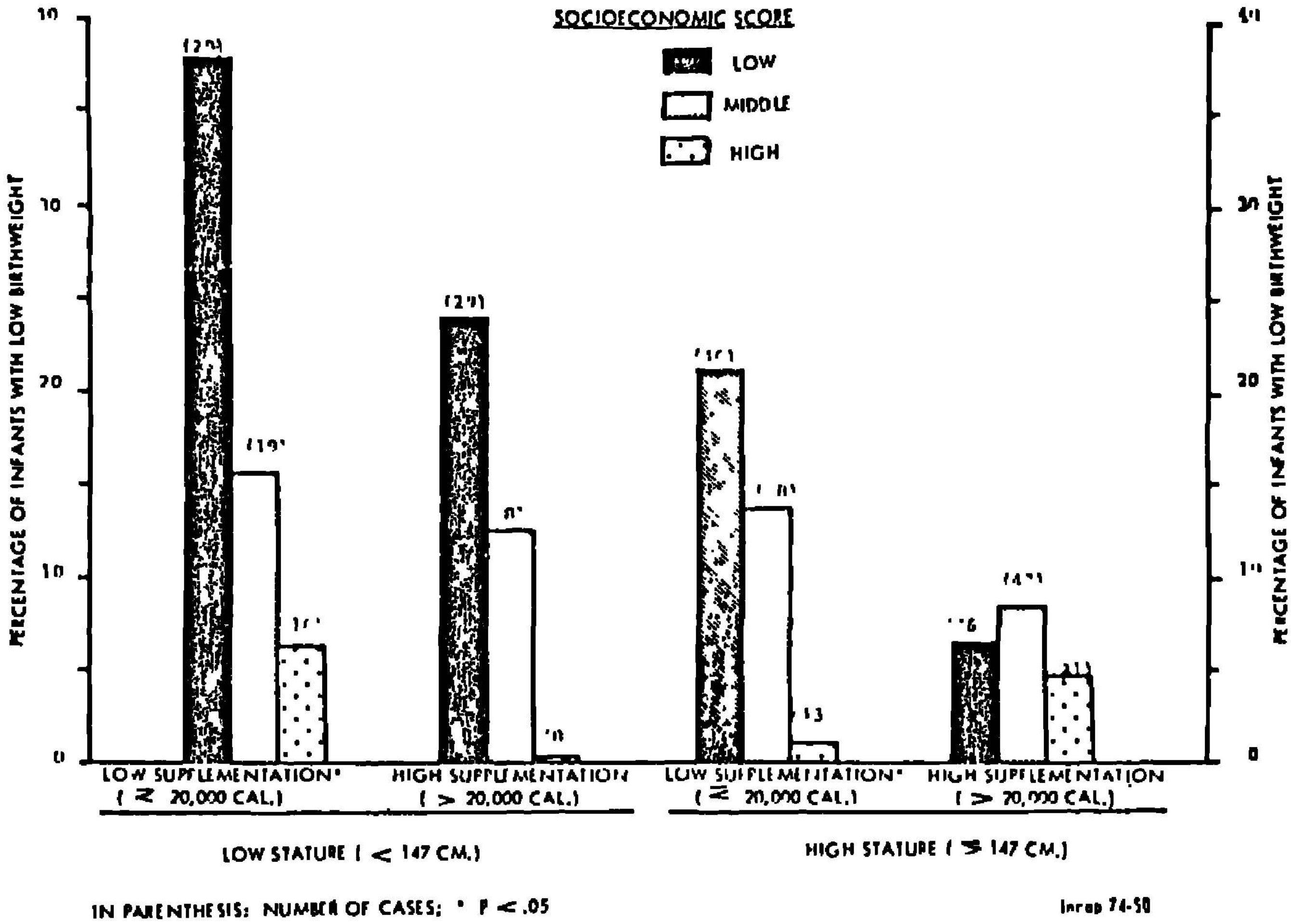
In the high caloric supplementation group, this addition amounted to approximately 35,000 calories during the course of pregnancy, or about 125 calories/day extra.

This association between caloric supplementation and birthweight is not explained by other important maternal variables such as size, home diet, morbidity, obstetrical characteristics or socioeconomic status. More importantly, this association was not produced by undetected confounding factors related to the mother (such as a tendency for some women to have bigger babies) since it was also observed across two consecutive births for the same mother. That is, if a woman consumes more supplemental calories during one pregnancy than during another, there is a tendency for the baby of that pregnancy to be heavier at birth. Thus based on the pattern of findings, we have concluded that caloric supplementation during pregnancy is causally associated with the decrease in small babies in this population (Lechtig et al., 1975).

So far, we have presented data to argue that factors such as socioeconomic status do not confound the birthweight findings reported. This, however, does not mean that socioeconomic status is unimportant (Klein, et al., 1973). Figure 2 shows that in our study population family socioeconomic status (SES), as well as maternal height, is associated with birth-

FIGURE 2

Influence of Maternal Height and Caloric Supplementation During Pregnancy On the Relationship Between Socioeconomic Score and the Proportion of Infants with Low Birthweight



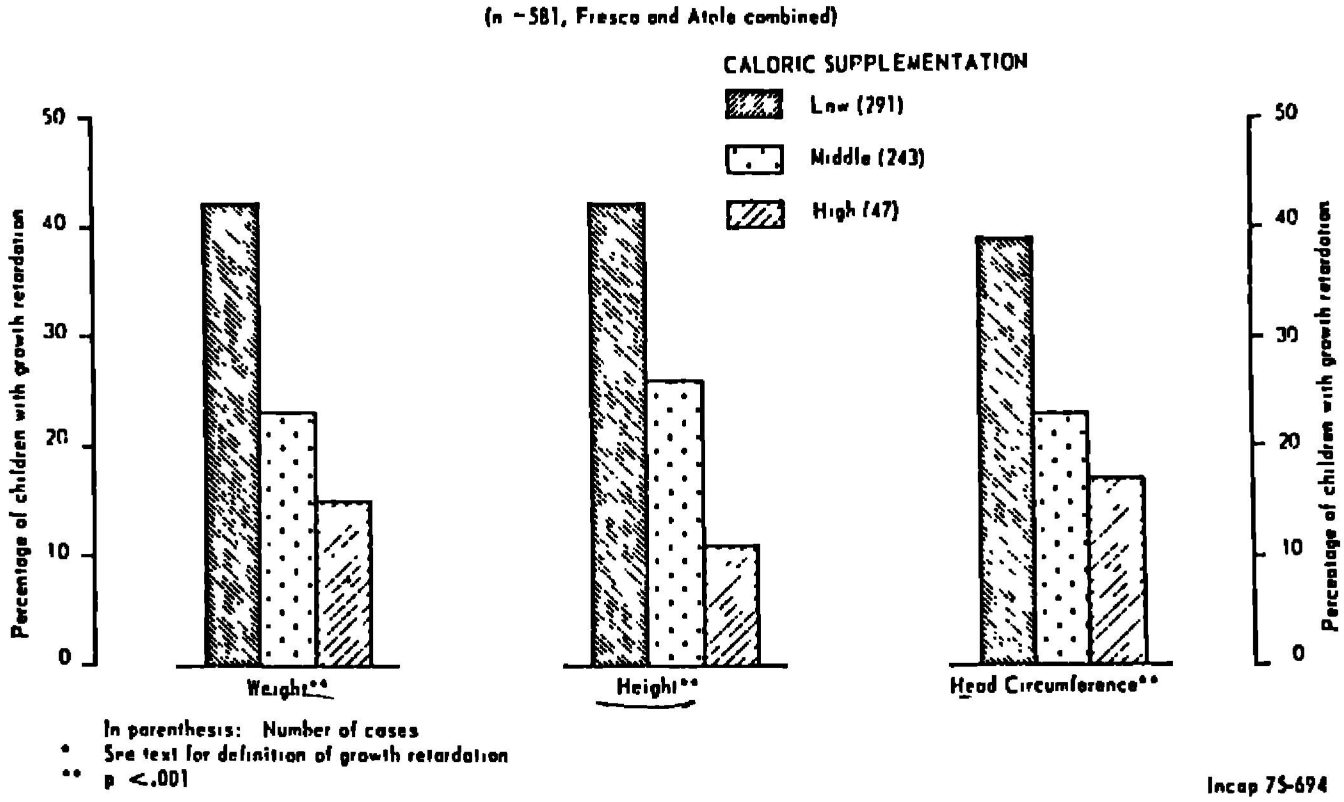
weight. In fact, the impact of this variation in poverty within these four rural villages is as great as the impact of the nutritional intervention.

Supplement Ingestion and Growth. For these analyses we define retardation in growth, whether in weight, height or head circumference, as being below the 30th percentile of the study population distribution. These limits are below the 10th percentile of the distribution of a well-nourished reference sample from Denver, Colorado (Hansman, 1970). Since we do not believe these populations differ in genetic potential The moderately supplemented group consisted of children who did not (Habicht et al., 1974; DDH/INCAP, 1975), we regard these deficits as true retardation.

Figure 3 shows the proportion of children with retardation in weight, height, and head circumference at 36 months of age for the poorly, moderately and well supplemented groups. The poorly and well supplemented groups consisted of those children who ingested, either directly or through their mothers, less than 5,000 or more than 10,000 supplemented calories per quarter, respectively, during at least 11 quarters.

FIGURE 3

Relationship Between Categories of Caloric Supplementation Since Conception and Percentage of Children with Growth Retardation* in Weight, Height and Head Circumference at 36 Months of Age (N = 581, Fresco and Atole combined)



fall in either the low or the high groups. There is a strong relationship between level of supplementation and physical growth retardation.

It is also clear, however, that in the fresco villages there is a higher rate of growth retardation in the moderately supplemented group than there is in the atole villages. Although consumption of calories is generally lower in the fresco communities because of the make-up of the supplement beverage, this does raise the question of the separate effects of protein and calories in the child's consumption. This issue is currently being explored. However, it should be stressed that within each of the four villages there was a consistent and statistically significant difference by level of caloric supplementation in the proportion of children showing growth retardation. This proportion is consistently greater in the poorly supplemented group than in the moderately or well supplemented groups. In the total sample, the risk of growth retardation is almost three times greater in the poorly supplemented than in the well supplemented group.

Determinants of Psychological Test Performance

Supplement Ingestion and Psychological Test Performance. The principal hypothesis of the longitudinal study is that mild-to-moderate malnutrition, a condition affecting the majority of children growing up today in developing countries; affects the mental development of these children. Preliminary data strongly suggest the hypothesized relationship does indeed exist. Tables 1, 2, and 3, present mean psychological test scores at ages three, four and five years for children falling into three supplementation categories, plus analysis of variance test F values. It should be noted that both a composite score, constructed by standardizing and then summing test scores, as well as several individual test scores show sig-

TABLE 1

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[1]

Tests	Supplemental Categories 1		2		3		SD	F
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)	8.01	(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)	21.18	(137)	20.61	0.38
Knox Cubes	0.62	(88)	0.41	(16)	0.69	(62)	1.30	0.65
Draw-A-Line Slowly	10.22	(412)	9.57	(113)	8.90	(147)	4.41	5.09**
Persistence on an Impossible Puzzle	5.91	(361)	7.03	(116)	6.51	(118)	5.31	2.15

[1] Caloric Supplementation/Quarter:
Category 1 (< 5,000 Cals.)
Category 2 (5,000-9,999 Cals.)
Category 3 (≥ 10,000 Cals.)

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

TABLE 2

Means, Pooled Standard Deviations and Analysis of Variance F Values of Psychological Test Scores at 18 Months for Children Falling into Various Cumulative Supplementation Categories[1]

Test	Supplemental Categories 1		2		3		SD	F
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	(418)	22.18	(128)	21.65	(115)	11.90	0.14
Sentence Memory	31.94	(412)	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	(419)	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

[1] Caloric Supplementation/Quarter:
Category 1 (< 5,000 Cals.)
Category 2 (5,000-9,999 Cals.)
Category 3 (≥ 10,000 Cals.)

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

nificant effects of nutritional supplementation at each age. The tests which show nutritional effects cover a wide range of skills, including verbal reasoning, learning and memory, and visual analysis, with the magnitude of the effect being generally from one third to one half of a standard deviation. However, as a careful examination of Tables 1, 2, and 3 indicates, we are not able to pinpoint specific abilities which are con-

TABLE 3

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[1]

Tests	Supplemental Categories 1		2		3		SD	F
Composite Score	—0.70	(452)	0.87	(135)	1.90	(101)	7.61	6.05**
Embedded Figures	4.12	(450)	4.40	(135)	4.81	(103)	2.21	4.72**
Digit Memory	35.82	(411)	35.20	(135)	31.09	(103)	13.10	0.75
Sentence Memory	51.27	(412)	51.56	(131)	52.17	(101)	21.16	0.08
Vocabulary Naming	17.08	(419)	18.78	(135)	18.40	(101)	5.06	7.53**
Vocabulary Recognition	30.08	(419)	31.13	(135)	31.35	(101)	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	3.41	(202)	4.74	(88)	4.91	(89)	3.53	7.57**
Conservation of Material	0.29	(197)	0.31	(86)	0.26	(86)	0.60	0.10
Conservation of Area	0.35	(193)	0.10	(85)	0.38	(87)	0.67	0.16
Conservation of Cont. Quality	0.20	(202)	0.21	(86)	0.17	(87)	0.13	0.17
Incomplete Figures	5.59	(203)	5.73	(86)	5.15	(81)	2.61	1.15
Elimination	5.10	(199)	5.21	(88)	5.33	(87)	2.16	0.10
Block Design	39.58	(202)	42.81	(88)	47.75	(88)	20.16	5.01**
Incidental Learning	1.31	(418)	1.77	(135)	1.79	(103)	1.27	9.36**
Intentional Learning	2.18	(418)	2.41	(135)	2.87	(103)	1.10	10.96**
Haptic-Visual Matching	3.86	(351)	4.22	(126)	4.45	(103)	2.87	2.01
Face-Hands	2.11	(200)	2.37	(87)	2.12	(87)	1.39	0.09
Matching Familiar Figures	2.75	(413)	2.85	(131)	2.86	(103)	1.35	0.51

TABLE 3 (*continued*)

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**

[1] Caloric Supplementation/Quarter:
Category 1 (< 5,000 Cals.)
Category 2 (5,000-9,999 Cals.)
Category 3 (≥ 10,000 Cals.)
* $p < .05$
** $p < .01$

sistently affected by early malnutrition. Not all of the tests which appear to measure similar cognitive skills (e.g., memory for digits, memory for sentences, memory for objects, memory for designs, etc.) show identical relationships to malnutrition. Furthermore, given that a cognitive test which measures children well at one age does not necessarily do so at other ages, we must now a) investigate more closely each specific test and attempt to precisely define what abilities each test measures, and b) search for ways of identifying the effects of malnutrition on these various cognitive abilities.

We have also attempted to determine if crucial periods exist in which nutritional supplementation has a particularly strong impact upon subsequent cognitive performance. To examine this question, we have employed regression analyses in which supplementation during various epochs was regressed on psychological test performances at ages three and four. These analyses were uninterpretable at five years of age due to insufficient numbers of children who had been well supplemented very early in life. These analyses suggest that the period from birth to 36 months is the most important in determining later test performance.

Social and Economic Factors and Psychological Test Performance. We have investigated the possibility that non-nutritional variables may be confounded with and responsible for the associations between food supplementation and mental development. For example, it is possible that, in a quasi-experimental study like ours in which the treatment (supplement ingestion) was entirely voluntary, bright cooperative families would drink more supplement and perform well on tests of mental development without ingestion and good performance being causally related. Or it might be that the stimulating effect of attending the supplementation centers per se, rather than supplement ingestion, made children more intelligent; or that poorly supplemented children were also sicker and being sicker made them perform less well. However, each of these plausible alternative explanations has been statistically tested and rejected.

Perhaps the most plausible alternative explanation of our finding of an association between food supplementation and mental development is family socioeconomic status (SES). It is generally known that family characteristics are consistently associated with mental test performance (e.g., Whitemen and Deutsch, 1968; Hess, 1970) and this was also true in these villages. Family SES level also generally covaries with children's home diet in untreated populations. For these reasons, family SES must be carefully measured and controlled for in studies of malnutrition and mental development (Klein et al., 1976).

In the present study, family SES level is unrelated to supplement ingestion. Furthermore, we know the associations between supplementation and mental test performance are not merely due to SES differences between good and poor test performers. Regression analyses in which successive offspring of the same mother are compared have been performed. These analyses, by making within-family comparisons, hold constant family variables including SES level. They indicate mental test performance differences as a function of differences in supplementation within families as large as the between family effects cited earlier. These findings parallel those related to supplementation and birthweight.

Family SES level does appear to interact with supplementation 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. This is illustrated in Table 4, which contains contingency tables showing the percentages of children falling into the upper and lower 20% of the composite score distribution at three, four, and five years as a function of supplementation category membership from 0-36 months and SES level.

It will be noted that low SES children who received very little supplementation were at greater risk of poor test performance than higher SES children receiving similarly low levels of supplement. Children from high SES families were, though barely supplemented, as likely or more likely to be at the top as opposed to the bottom of the distribution. Thus, it appears that poor nutrition from 0-36 months is more damaging to children from lower SES families than to those from more advantaged families.

TABLE 4

Numbers of Children in Lowest Supplementation Category Falling into the Lowest Percentile of Composite Score Performance or Not, by SES Level

		Lowest Percentile	*Higher Percentile*	
3 Years:				
	Low SES	61	166	Relative Risk = 1.41*
		47	200	
4 Years:				
	Low SES	82	169	Relative Risk = 2.10**
		43	233	
5 Years:				
	Low SES	69	183	Relative Risk = 1.68**
		47	241	

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

As we have noted, family SES variations not only interacted with nutritional status to affect mental development, but also appear to have exerted an effect directly upon mental development. Tables 5 and 6 present regression analyses which reveal the contribution of various social-environmental, nutritional and anthropometric domains to mental test performance. Variables were entered into each regression equation in a stagewise fashion. In these analysis SES is defined as a composite of two family economic indicators—1) house quality (an index of type of house construction and number of rooms, which has been found to be a stable index of family wealth) and 2) the quality of parent's clothing, which is an index of more liquid wealth. Home characteristics consist of a number of family measures constructed to index aspects of intellectual stimulation available in the home. These are: Mother Composite, which combines the mother's vocabulary test score, literacy test score, years of school passed, and modernity into a single index of intellectual characteristics; Sibling Schooling, which indexes average years passed by all older siblings living

Table 5

Regression Analyses—Females Three and Four Years of Age

Test	Age	N	R^2 SES	R^2 Home Characteristics	ΔR^2 Treat	ΔR^2 Anthrop.	R^2 Total
Embedded Figures	3	177	.000	.027	.028	.051	.106
	4	189	.002	.016	.006	.022	.045
Digit Memory	3	151	.001	.047	.078*	.043	.168*
	4	186	.007	.036	.012	.042	.090
Sentence Memory	3	157	.003	.067	.022	.033	.122
	4	184	.002	.022	.011	.055*	.089
Vocabulary	3	171	.017	.054	.018	.047	.118
	4	191	.039*	.078*	.048*	.108***	.234***
Verbal Inferences	3	69	.007	.079	.112	.037	.246
	4	154	.003	.027	.011	.048	.086
Line Velocity	3	170	.019	.067	.161***	.034	.262***
	4	188	.046**	.045	.050*	.058*	.153**
Memory for Objects	3	100	.004	.044	.023	.146**	.203
	4	118	.027	.056	.044	.093	.193
Cognitive Composite	3	178	.005	.042	.026	.108***	.176**
	4	194	.031*	.042	.015	.129***	.186**

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

TABLE 6

Regression Analyses—Males Three and Four Years of Age

Test	Age	N	R^2 SES	R^2 Home Characteristics	ΔR^2 Treat	ΔR^2 Anthrop.	R^2 Total
Embedded Figures	3	206	.012	.083*	.039	.041	.163**
	4	208	.012	.039	.017	.027	.083
Digit Memory	3	180	.019	.035	.022	.015	.073
	4	198	.021	.109**	.009	.012	.130*
Sentence Memory	3	186	.008	.050	.036	.032	.118
	4	196	.012	.095**	.033	.026	.154**
Vocabulary	3	200	.035*	.049	.046	.045*	.140*
	4	204	.063**	.109**	.052*	.034	.195***
Verbal Inferences	3	88	.008	.100	.155**	.016	.271*
	4	165	.005	.036	.094**	.029	.159*
Line Velocity	3	197	.016	.039	.052*	.035	.126*
	4	204	.014	.027	.036	.049*	.112
Memory for Objects	3	120	.017	.106	.104**	.096**	.306***
	4	130	.054*	.166*	.006	.039	210*
Cognitive Composite	3	210	.027*	.094*	.066**	.056**	217***
	4	210	.057**	.144**	.078**	.033	.255***

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

at home; and Books and Objects, which is an index of the number of books, magazines, and visually stimulating objects such as drawings, photographs, and pictorical calendars present in the home.

Anthropometry may be considered a proxy for those nutritional and environmental characteristics which were unknown and unmeasured; in this case for example it may reflect the unmeasured effect of home environment and home diet. In about one-third of the regressions, the amount of variance explained by the treatment is statistically significant even when family SES and home characteristics have been taken into account. It is apparent from these analyses that not only nutrition, but also family economic level and resources of intellectual stimulation in the home influence mental development in the study communities. The additional impact of the anthropometry, as a proxy for unmeasured variables, is noteworthy and suggests the need for a reanalysis of current models and a review of measurement strategies.

Work is proceeding on the development of more measures descriptive of the home environments of the children in our study, from data collected under the auspices of another investigation. Multivariate analyses of the complicated and important interrelationships among nutritional status and these environmental influences on mental development are planned.

DISCUSSION

Results to date of the INCAP study suggest that there is an effect of malnutrition on mental development, that the period when nutrition is of greatest importance is the first three years of life, that the effect of poor socioeconomic environment exacerbates the effects of early malnutrition and that SES and other environment characteristics contribute independently to the mental development of children. These data suggest more strongly than previous studies that the effects of malnutrition on mental development are causal. Parenthetically, it should be noted that research not discussed in the present paper has helped us to define the meaning and validity of the concept of mental development in the study communities. We know for example that children who performed well on our tests at age three, four, and five subsequently entered school earlier than peers who did not perform well, stayed in school longer, and received higher grades from their teachers. These children are also perceived by village adults as more "listo" than peers. "Listo" translates to English as smart, and connotes a child with verbal skill, a good memory, and a high level of physical activity.

The issue of calories requires further comment. The fact that the effect observed on birthweight where isocaloric comparisons are possible was similar for calories with or without proteins indicates a caloric rather than a protein effect. This finding is consistent with analyses of home dietary intake data showing dietary deficiencies in calories but not in protein. Thus, we believe it feasible to improve the total diet of mothers and children by adding more calories in the form of supplement. In other populations with different patterns of dietary intake the situation could be quite different. The best supplement for one population need not be the best and indeed may even be harmful for another.

Furthermore, we wish to emphasize that the technique of food supplement as employed in this investigation is primarily a research tool and that programs of this type are inappropriate for large populations over long periods of time. Analyses reviewed in this paper would suggest that to maximize the impact on mental development one would develop both nutritional and social interventions. However, in developing countries, the ultimate solution to problems of malnutrition and its accompanying development retardation would be the elimination of poverty. In the meantime, public health programs with strong nutritional components can do much to reduce growth retardation, infant mortality and reduce the risk of less than optimal mental development.

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