Nutrition and Cognitive Development among Rural Guatemalan Children

HOWARD E. FREEMAN, PHD, ROBERT E. KLEIN, PHD, JOHN W. TOWNSEND, PHD, AND AARON LECHTIG, MD

Abstract: Women and children from four Guatemalan villages participated in a voluntary food supplementation program for seven years. In two of the villages, they received a vitamin and mineral fortified, high-protein calorie supplement. In the other two villages, the vitamin-mineral fortified supplement contained no protein and a relatively small number of calories.

Cognitive tests were administered regularly to children ages three to seven, and anthropometric measures obtained. In addition, measures of families' social milieu were collected at several points in time.

Using multiple regression analysis, we find that both nutritional and social environmental measures are related to various dimensions of cognitive competence. The results suggest that nutritional intake, independent of social factors, affects cognitive development. There is also some evidence that the children who receive the high-protein calorie supplement (and whose mothers received it during pregnancy and lactation) are more likely to score high in cognitive performance. Our results, while not diminishing social environmental explanations of differences in cognitive function, suggest benefits from nutrition intervention programs in rural areas of lesser-developed countries. (*Am J Public Health* 1980; 70:1277-1285.)

During the past 20 years, there has been a proliferation of studies of the effects of childhood malnutrition on physical and mental development.[1] The continued concern with the impact of malnutrition on physical and mental development is related to an inability to control population growth in lesser-developed countries, marginal food production on a world-wide basis, and inequitable food distribution even within our most industrialized countries. It is further stimulated by competition for the resources of governments, international agencies, and private foundations by advocates of nutrition intervention programs and those whose priorities lie in such other sectors as education and rural economic development. In addition to the press for findings to support policies and programs of nutrition intervention, the spate of investigation is an effort to extend and clarify animal studies of the relationship between malnutrition and neurological development, learning patterns, and other behaviors.[2-5]

Over the several decades of work, attention has shifted to a large extent from studies of the cognitive performance of severely malnourished children to investigations of those with mild and moderate protein-calorie deficiencies. An estimated three per cent of the world's children undergo one or more episodes of severe malnutrition prior to their fifth birthday.[6] In comparison, it is estimated that fully one-half of the pre-school children in lesser-developed countries are suffering from mild to moderate protein-calorie deficits, as well as a small, but critical, proportion of children in low-income families in industralized nations.[7]

Extrapolating the findings of early studies documenting a presumably causal link between children's severe nutritional deficiencies and their reduced cognitive development[8-12] to moderately and mildly nourished children has resulted in a continuing and intense scientific and policy debate. The controversy involves both the extent to which findings about severely malnourished children can be generalized to mild and moderate ones, and whether a causal relationship can be accepted on the basis of epidemiological data.

A causal linkage between mild and moderate malnutrition and intellectual development is challenged by findings of numerous investigations in both lesser-developed and industrialized countries. These range from broad investigations that find an association between children's social milieu and cognitive devlopment[12] to specifically nutrition-focused studies, such as those of Evans and associates' South African investigation in which malnourished children and their healthier siblings achieved similar scores on cognitive tests.[13] Moreover, children in economically advantaged families have been found repeatedly to have larger anthropometric measurements on indicators commonly used to evaluate nutritional status. Thus, there is a strong argument that the relations between mild to moderate malnutrition and level of cognitive functioning is explainable by the covariation between socioenvironmental factors and nutritional status.

Adequate study of the competing explanations—nutritional status vs socioenvironmental factors—involves complex issues of conceptualization, design, analysis, and protection of human subjects. The immature state of the nutri-

Address reprint requests to Dr. Howard E. Freeman, Director, Institute for Social Science Research, University of California, Los Angeles, CA 90024. The other authors are all with the Institute of Nutrition of Central America and Panama (INCAP). Dr. Klein is Director of INCAP Division of Human Development and Drs. Townsend and Lechtig are senior staff members in this Division. This paper, submitted to the Journal June 16, 1980, was revised and accepted for publication August 20, 1980.

tional and behavioral sciences does not permit complete solutions to the major problems of method, including adequate operationalization and measurement of key variables (see Klein, *et al,* for an expanded discussion of this point[14]). Further, the number of variables that must be quantified and introduced into any reasonable design requires relatively large samples, collection and collation of data on extensive sets of variables and, consequently, sophisticated data analysis procedures.

The importance of the issue, however, and particularly the policy concern with nutritional interventions in lesser-developed countries, led to initiating a number of field investigations in the mid-1960s. These studies necessarily began with less than perfect designs, and are deficient to varying extents because of implementation difficulties that could not be fully overcome. Nevertheless, their results promise to refine knowledge about the causal impact of nutrition on cognition (see Klein, *et al,* for reports about these efforts, as well as a discussion of their methodological limitations[15]).

The data reported here come from a long-term longitudinal Guatemalan investigation of nutrition and mental development which began in 1968, and was recently completed by the Institute of Nutrition of Central America and Panama (INCAP).[16-18] In two earlier papers, we reported preliminary analyses of the contributions of nutritional and social factors to cognitive functioning.[14,19]

The results of these early analyses suggested that both the nutritional and social domains are related to cognitive development among three and four year old children, and that the relative importance of nutritional and social factors depends on the particular cognitive dimension selected as the criterion variable. There were major sex differences in the amount of variance accounted for by the different social and nutritional measures included as independent variables. While findings had limited robustness, the results suggested that nutritional status had an independent, presumably causal, linkage to at least several of the important dimensions of cognitive functioning, as well as to a composite measure of mental development.

In this paper, we provide an analysis of the final data set on the contributions of nutritional and social factors to cognitive development. The analysis is expanded substantially: rather than having test scores at only ages three and four, we have data for children from ages three years through seven years. Furthermore, sample sizes, compared with the earlier reports, have increased.

The INCAP Study, Design and Methods

The study population consists of children from four small Spanish-speaking Guatemalan villages. In 1972, average family incomes were less than $300 per year. Most adults cannot read or write, almost no families have indoor sanitary facilities, and the water generally is contaminated with enteric bacteria. Corn and beans are the major diet, and animal protein is less than 12 per cent of total protein intake.[20]

TABLE 1—Number of Children Available for Analysis by Age and Sex

	Age at Time of Testing				
Sex	3 years	4 years	5 years	6 years	7 years
Male	396	463	428	403	371
Female	341	397	405	388	368

Study Design

The study can most properly be described as a quasi-experiment.[21] In two of the villages, pregnant and lactating mothers and children were offered a protein-calorie supplement twice a day. In two other villages, a supplement containing no protein was provided. This supplement, a fruit-flavored drink, contains one-third of the calories (59 compared with 163 per ml) of the protein-calorie supplement. Both include vitamins, minerals, and fluorides limited in the home diet. In this paper the protein-calorie supplement will be referred to as the "high calorie supplement." Attendance at the supplementation program was voluntary, and there were no restrictions on how much could be ingested. A wide range of intake occurred.

The high-protein calorie supplementation in two of the four villages provides an overall study group that includes sufficient children and lactating mothers with an adequate calorie intake. Without "salting" the study group with supplemented children and mothers, the proportion malnourished in rural Guatemalan villages is so large it would not be possible to undertake the analysis. The impact of supplementation on physical growth is clear, with significant differences observed in anthropometric measures among children at birth and all ages.[22,23]

The Subjects

The analysis includes 1,083 children, 671 born alive after the field work started in 1969, and 412 alive, and between three and seven years of age when data collection commenced.

Thus, at each age the number of children available for analysis consists of those of that age in the villages when the study began and first testing occurred, plus children who "grow up" to each age and were tested at that age-point. The number of children for which data are available at various ages also differs because there was mobility both in and out of the villages throughout the study. Also, sometimes children were unavailable in particular years for psychological testing and anthropometric measurement.

This point requires some additional amplification. When data are presented by age, the age designation refers to the information collected at a particular time point, e.g., information reported for age three, and then for age five, includes many of the same children in the two analyses, but the data differ by time point collected. The study group sizes by age and sex are reported in Table 1. The exact study group sizes for each analysis vary somewhat because of missing data; in general, subsequent tables contain about 95 per cent of the study groups' size reported in Table 1.

Variables

In this paper we include four sets of data from the unusually large corpus of information available. The variables selected are the same as reported in the two earlier articles.[14, 19]

Dependent Variables

The cognitive measures used come from a specifically designed "preschool" battery. Three specific measures are employed, as well as a composite index.

Language Facility—The score is based on the child's ability to name and recognize pictures of common objects, and to note and state relations between orally presented verbal concepts.

Short-Term Memory for Numbers—The child's score is based on recall of increasingly long strands of numbers, read at the rate of one per second.

Perceptual Analysis—Scores of children are based on the ability to locate hidden figures imbedded in a complex picture.

Cognitive Composite—Results were first standardized and then added together on 12 tests to obtain the composite score. The cognitive composite summarizes the child's ability to memorize, recognize, perceive, infer, and verbalize.

Test-retest reliabilities differ somewhat by age, but are generally within the accepted .7 to .8 range when measures are obtained one month apart. The test-retest reliability of the cognitive composite battery so obtained was .88 for three year old children.

Socioenvironmental Measures

Although the villages are relatively "flat" in stratification, nevertheless there is evidence of structural and life-style variation. After attempts to develop a range of scales, it was decided to obtain family data repeatedly on three measures. The data used here were obtained in the third (1974) survey:

Quality of House—Rating based on the type of construction, interior design, and condition of dwelling. (Test-retest reliability = .80.)

Mother's Dress—Rating based on whether or not the mother possessed specified items of commercially manufactured clothing. (Test-retest reliability = .65.)

Task Instruction—Rating based on family members' reports of teaching the child to perform household tasks and to travel to a nearby town. (Test-retest reliability = .50.)

The first measure, quality of house, is conceived as a social-economic stratification measure. The second, mother's dress, reflects modernity as well as income. The third, task instruction, is viewed as an indicator of the parents' efforts to provide adult modeling and purposeful learning opportunities. Reliability of the two stratification measures is reasonably high, particularly the quality of house measure. The task instruction measure's reliability is borderline. Reliability of measures is increased by pooling the three scores. The composite measure is referred to as the "social factor index." The test-retest reliability of the social factor index is .85.

Nutritional Data

The child's head circumference and total height are used as indices of nutritional status. Both variables presumably reflect the child's history of protein-calorie intake, although genetic background and illness experience also influence them. Height is generally the best indicator of extended nutritional deficiency; head circumference is most sensitive to malnourishment before the age of two years.[24] Extensive field trials conducted as part of the INCAP program argue for the utility of anthropometric measures as indicators of nutritional status. As previously reported, INCAP field surveys have found that in villages in which children receive an annual intake of more than 20 liters of the high calorie food supplement, their physical growth velocities are similar to those recorded for children in the United States.[14] In villages receiving the low-calorie supplement, these velocities are significantly lower. The height and head circumference measures are combined into a *Nutrition Index* by first standardizing and then adding the values together.

Supplementation Data

Children and their mothers received and drank the supplements under supervision, with careful recording of amounts. Three different measures are used in this analysis: the caloric intake of mothers during gestation, their intake during lactation, and the total calories consumed by the children from birth until seven years of age.

In the two villages receiving the high calorie supplement during both pregnancy and lactation, mothers consumed at least twice as many calories as in the villages receiving the low calorie supplement. Children in the high calorie villages, depending upon the age point studied, received anywhere from two to six times the number of calories (see Table 2).

Results

Separate multiple regression analyses with the data pooled for the four villages were undertaken by age and sex. A large number of repeated analyses were performed. First, in order to estimate the independent and joint effects of variables in the several domains of measures, they were "forced" into the analysis in different orders (for example, social factors first and then nutritional measures).

Second, analyses were undertaken with individual measures and with composite indices. While indices minimize the number of variables, conserve the degrees of freedom, and simplify interpretation and presentation of findings, the amount of variance explained may be reduced since the components in the composite indices are not highly correlated with each other.

Third, analyses were undertaken with and without taking into account interaction effects between variables. There

TABLE 2—Average Total Supplement Consumed (Kcal × 100) by Age of Child

	Age									
	3 years		4 years		5 years		6 years		7 years	
	Type of Supplementation Children Received*									
	H	L	H	L	H	L	H	L	H	L
Mothers during Gestation	138	95	120	80	74	61	42	26	15	9
Mothers during Lactation	232	51	197	42	150	35	121	26	56	14
Male Children	1180	193	1533	362	1797	572	1986	740	2069	920
Female Children	1004	166	1452	334	1652	507	1984	656	2069	904

*H = High Protein Calorie Supplement (11g of protein and 163 Kcal/180 ml.)
L = Low Calorie (No Protein) Supplement (59 Kcal/180 ml.)

were no interaction effects important enough to include in this report. The variance explained by them was not statistically significant and was outweighed by the loss of degrees of freedom. Finally, a further refinement was to adjust correlations for estimated reliability of measures. Again, this procedure does not modify the results.

Nutrition and Cognitive Performance

In Table 3, we present the zero-order correlations of the nutritional measures and the psychological test scores. The R^2 of the two nutrition variables, height and head circumference, and the psychological test scores are included.

TABLE 3—Correlations between Nutritional Status and Cognitive Measures

	Test							
	Language		Memory		Perception		Composite	
	M	F	M	F	M	F	M	F
Nutritional Index								
Age 3	.27**	.28**	.12*	.31**	.13*	.24**	.22**	.40**
4	.23**	.37**	.04	.22**	.15**	.07	.21**	.34**
5	.30**	.34**	.15**	.23**	.20**	.20**	.29**	.32**
6	.38**	.34**	.10	.13*	.16**	.22**	.29**	.29**
7	.32**	.36**	−.03	.22**	.13*	.32**	.22**	.37**
Height								
Age 3	.30**	.26**	.17**	.28**	.14**	.19**	.26**	.32**
4	.26**	.32**	.11*	.19**	.15**	.04	.26**	.29**
5	.29**	.27**	.19**	.18**	.17**	.20**	.28**	.26**
6	.27**	.28**	.10	.11*	.15**	.13*	.23**	.23**
7	.24**	.30**	.00	.20**	.12*	.28**	.15**	.33**
Head Circumference								
Age 3	.17**	.24**	.03	.25**	.08	.23**	.10	.36**
4	.12*	.32**	−.05	.18**	.10*	.06	.10*	.30**
5	.21**	.31**	.07	.22**	.15**	.13**	.20**	.29**
6	.35**	.28**	.06	.10	.11*	.23**	.25**	.25**
7	.28**	.29**	−.05	.16**	.10	.25**	.21**	.29**
R^2 of Height and Head Circumference								
Age 3	.09**	.08**	.03*	.10**	.03*	.06**	.07**	.16**
4	.07**	.14**	.02*	.06**	.02*	.00	.07**	.13**
5	.10**	.12**	.04**	.06**	.04**	.05**	.09**	.11**
6	.15**	.11**	.02	.02	.03*	.06**	.09**	.08**
7	.11**	.13**	.02	.05**	.02	.10**	.06**	.14**

*P < .05; **P < .01

The overall conclusion is clear. Both independently and taken together either as a summated index or in terms of a multiple regression result, nutritional status is related to cognitive competence. The results are striking in the case of both language and the cognitive composite measure. The two nutrition variables taken together explain at all ages approximately 10 per cent of the variance in language scores and, at all ages, at least 7 per cent of the variance in cognitive composite scores.

Memory results are less consistent, particularly for males; relations between the nutrition measures and perception are somewhat more consistent and higher for older female children than for older male children. It is difficult to explain the spottiness of the correlation values for the memory variable. The low values at four years for the perception measure is accountable by the design of the test. At age four, the test was made more difficult in order to avoid ceiling effects (it would have probably been better to increase the level of difficulty at age five rather than four). The level of difficulty of the test accounts for the reduced amount of variance explained.

The variations in the correlations of height and head circumference may be explained by the age-ceiling on head circumference; most of the variation takes place by 24 months of age. In contrast, height is sensitive to health and nutritional insults throughout childhood. In any event, consistent with epidemiological studies of nutritional status and intellectual development and our previously reported analyses, there is in general, a clear association between nutritional status and cognitive measures.

Social Factors and Cognitive Scores

Socioenvironmental factors as well as nutritional status are related to cognitive scores. In Table 4 we report zero-order correlations for the three individual measures—quality of housing, mother's dress, and task instruction—and for the social factor index. With respect to language, the three individual variables, as well as the social factor index, are signif-

TABLE 4—Correlations between Social Measures and Cognitive Scores

	Test							
	Language		Memory		Perception		Composite	
	M	F	M	F	M	F	M	F
Social Factor Index								
Age 3	.20**	.13*	.13*	.01	.11*	−.01	.18**	.05
4	.19**	.19**	.15**	.08	.13**	.04	.23**	.19**
5	.31**	.22**	.18**	.18**	.10*	.08	.34**	.20**
6	.24**	.28**	.22**	.24**	.16**	.09	.27**	.31**
7	.26**	.34**	.13*	.24**	.10	.18**	.21**	.36**
House Quality								
Age 3	.07	.14*	.05	−.02	.01	.02	.05	.08
4	.05	.16**	.05	.09	.03	.02	.08	.17**
5	.15**	.17**	.11*	.16**	.06	.07	.18**	.18**
6	.13*	.22**	.14**	.15**	.14**	.04	.13*	.23**
7	.15**	.29**	.13*	.14**	.05	.20**	.14**	.32**
Mother's Dress								
Age 3	.19**	.06	.15**	.00	.08	−.04	.20**	.02
4	.22**	.17**	.19**	.09	.13**	.04	.26**	.17**
5	.26**	.17**	.10*	.12*	.07	.02	.27**	.15**
6	.22**	.19**	.14**	.18**	.12*	.11*	.23**	.26**
7	.20**	.25**	.09	.19**	.07	.09	.16**	.27**
Task Instruction								
Age 3	.17**	.05	.08	.03	.14**	−.01	.14 **	−.00
4	.16**	.08	.08	−.03	.13**	.03	.17**	.05
5	.27**	.13*	.18**	.11*	.10*	.08	.29**	.09
6	.18**	.18**	.18**	.19**	.08	.06	.24**	.19**
7	.21**	.20**	.05	.22**	.09	.09	.17**	.18**
Multiple R^2								
Age 3	.05**	.02	.02	.00	.02*	.00	.05**	.01
4	.06**	.04**	.04**	.02	.03**	.00	.08**	.04**
5	.11**	.05**	.04**	.04**	.01	.01	.12**	.12**
6	.07**	.08**	.05**	.06**	.03*	.01	.09**	.10**
7	.07**	.12**	.02	.07**	.01	.04**	.05**	.14**

*P < .05; **P < .01

icantly correlated with test scores. The amount of variance explained by the three measures, depending upon age, ranges from 4 to 10 per cent. There is some trend, although not marked, for the measures to explain an increased amount of variance when children are older, particularly among females.

These social measurements are also strong predictors of memory scores, at least for ages five and six, and for females at age seven. The three social variables also predict perception scores, although many of the values are not significant or borderline in significance. The overall cognitive composite measure is quite consistently predicted by the three social factor measures, particularly at later ages for females. The combined amount of variance explained is considerable. Certainly the general direction of the correlations is consistent and strong enough to suggest a link between socioenvironmental differences and psychological performance.

Independent Impact of Nutrition and Social Factors

The data presented suggest that both domains of variables are related to psychological test performance. The issue is whether or not a statement can be made about the unique contributions of nutritional status and social factors to mental development. To put it another way, do the nutri-

TABLE 5—Proportion of Variance Explained by Nutrition and Social Factor Measures

	Test							
	Language		Memory		Perception		Composite	
	M	F	M	F	M	F	M	F
Nutrition Index Alone								
Age 3	.06**	.11**	.01*	.10**	.02*	.06**	.05**	.16**
4	.04**	.14**	.00	.05**	.02**	.00	.05**	.12**
5	.10**	.09**	.02**	.05**	.04**	.04**	.08**	.10**
6	.14**	.11**	.01	.02*	.03**	.05**	.09**	.08**
7	.10**	.14**	.00	.05**	.02*	.10**	.05**	.14**
Social Factor Index Alone								
Age 3	.04**	.02*	.02*	.00	.01*	.00	.03	.00
4	.04**	.04**	.02**	.01	.02**	.00	.05**	.03**
5	.10**	.05**	.03**	.03**	.01*	.01	.11**	.04**
6	.06**	.08**	.05**	.06**	.03**	.01	.07**	.10**
7	.07**	.11**	.02*	.06**	.01	.03**	.05**	.13**
Nutrition and Social Factor Index Combined								
Age 3	.08**	.12**	.03*	.10**	.03**	.06**	.06**	.16**
4	.07**	.14**	.02*	.05**	.03**	.00	.08**	.12**
5	.16**	.11**	.04**	.07**	.04**	.05**	.16**	.12**
6	.16**	.16**	.04**	.07**	.04**	.05**	.12**	.15**
7	.12**	.21**	.03*	.08**	.02**	.11**	.07**	.22**
Nutrition Index with Social Factor Index First Removed								
Age 3	.03**	.10**	.01	.10**	.01*	.06**	.03**	.02**
4	.03**	.11**	.00	.05**	.01*	.00	.03**	.10**
5	.05**	.07**	.01*	.05**	.02**	.04**	.04**	.09**
6	.11**	.07**	.00	.00	.01*	.04**	.06**	.04**
7	.07**	.09**	.01	.02**	.01	.08**	.03**	.09**
Social Factor Index with Nutrition Index First Removed								
Age 3	.02**	.01	.01	.00	.01	.00	.02*	.00
4	.02**	.01	.02*	.00	.01*	.00	.03**	.01
5	.06**	.01*	.02*	.01	.01	.00	.08**	.01
6	.02**	.04**	.03**	.05**	.01*	.00	.03**	.06**
7	.03**	.07**	.02**	.04**	.01	.01*	.02**	.08**

*P < .05; **P < .01

tional measures predict cognitive functioning after all of the variance that can be attributed to social factors is first removed, and vice-versa?

Multiple regressions were undertaken in which the social factors were forced first, followed by the nutritional terms, and then by the interactions between these measures. In other regressions, the nutritional measures and the height X head circumference interaction were first forced, followed by the social variables. The analyses were undertaken using the composite indices, as well as separate variables.

In Table 5 we show the proportion of variance explained when the composite, nutrition and social factor indices are regressed on the psychological measures. The results are substantially the same when the individual nutrition and social factor measures are used, although the amount of variance explained when the composite indices are used is somewhat lower.

In two-thirds of the regressions, the amount of variance explained by the nutrition index for the three specific psychological measures is statistically significant even when the social factor effects are first taken into account. In the case of the composite measure, all of the regression values are statistically significant. When the procedure is reversed, i.e., when the social factor index is forced in subsequent to removing variance explained by the nutrition measures, there continue to be a number of significant regressions. There are, however, proportionately fewer significant values than when social factors are first removed, and the magnitudes of the values, in general, tend to be lower.

Reasons for the sex differences in regression values and for the variations by test are difficult to explain. Study group sizes for the analyses provided here are large enough to minimize sample size fluctuation as the explanation. With the exception of the already discussed level of difficulty problem of the perception test at age four, there seems little reason to believe that the psychometric properties of the different tests explain the variations in correlation values. It seems clear that both nutrition and social factors independently contribute to cognitive performance, the results being most consistent for the language variable and the cognitive composite measure.

Impact of Supplementation

As in the previous analysis, based only on the children at younger ages and partial study groups, the data presented up to now in this paper make a substantial case for the view that inadequate nutrition is associated with lower cognitive performance. Statements of a causal nature, however, are risky from essentially correlational data. Fortunately, the information on intake of supplementation is available and provides, albeit limited, support for the causal character of the association between nutritional cognition.

In Table 6, the findings on supplementation and cognitive performance are shown. For each of the three psychological tests and the cognitive composite, zero-order values are shown between test scores and the amount of supplement consumed during gestation and lactation, and during the child's participation in the study. In addition, R^2 values are shown for gestation and lactation taken together, and also for gestation, lactation and child-consumed supplement.

Ideally it would have been desirable to have measures of home diet intake as well. Home nutrition surveys were regularly undertaken. They are not precise enough for use here, although they do provide evidence that the interventions are true supplementations and not substitutes for food normally eaten by the children.

Almost one-half of the multiple regressions that take into account supplementation of the child are statistically significant. In general, the language measure shows the most profound impact of the supplement, with enough significant relations with memory and perception to support an overall generalization that nutrition impacts on cognition. Although the amount of variation is low, the cognitive composite variable also supports this contention.

There are further internal comparisons that support the contention of a causal link between nutrition and cognition. Supplementation for children trails off as they become older because of the design of the study. Specifically, children who were older when the study began (for example, age six) had the least opportunity to participate in the supplementation intervention. Children conceived when the study was first implemented had maximum opportunity, through mother's supplementation and the child's own participation, to receive extra calories. Children who were four years at the study's termination, if continually exposed to the supplementation, and whose mothers also received supplementation, on the average would have consumed more than twice that of the seven-year-old group. The higher values between amount of supplement consumed and test scores at early ages, a consequence of the design of the intervention, provide an additional hint that nutritional status is causally linked to psychological competence.

Further, analyses were undertaken in which social factors were controlled first and then supplementation correlated with test scores. However, there are few significant correlations between social factor scores and supplements ingested; whenever there are significant correlations between these variables they are *negative*. Thus, social factors have no impact or slightly raise the correlational values shown in Table 6.

The data just presented require revising one finding disseminated from earlier INCAP analyses,[14, 25] namely that the relations identified between nutrition, supplementation, and cognitive scores were mainly due to the impact on the nutritional status of pregnant and lactating mothers, rather than on children after weaning. The data in Table 6 suggest that, if anything, it is the amount of supplement consumed by the child that is correlated with cognitive scores. This is most clear in the case of memory, and also with respect to cognitive composite results.

Discussion

This field study is hardly an ideal randomized design, and there are problems of validity of many of the variables, and of reliability with some of them—particularly the social

TABLE 6—Correlations between Supplementation and Test Scores

Test	Age									
	3 years		4 years		5 years		6 years		7 years	
	M	F	M	F	M	F	M	F	M	F
Language										
During Gestation	.09	.10	.11*	.11*	.09	−.02	.03	.03	.06	.04
During Lactation	.08	.14*	.12*	.17**	.05	.08	.07	.04	.08	.10
R^2 (G+L)	.01*	.02*	.02**	.03**	.01	.00	.00	.00	.00	.01
Of Child	.14**	.10	.16**	.20**	.11*	.12*	.15**	.14**	.11*	.18**
R^2 (G+L+C)	.02**	.02	.03**	.04**	.02	.02*	.02*	.02*	.01	.03**
Memory										
During Gestation	.05	−.00	.03	.04	−.04	−.07	−.04	−.05	−.09	−.04
During Lactation	.02	.15*	−.03	.09	−.07	−.05	−.06	−.03	−.03	−.04
R^2 (G+L)	.00	.01	.00	.01	.00	.00	.00	.00	.01	.00
Of Child	.12*	.13*	.02	−.01	−.00	−.11*	.01	−.16**	−.03	−.08
R^2 (G+L+C)	.02	.04*	.01	.01	.01	.01	.01	.03**	.01	.01
Perception										
During Gestation	.06	.05	.02	.02	.08	.08	.07	−.01	.08	.08
During Lactation	.05	.03	.11*	.06	.08	.01	.07	−.03	.04	.03
R^2 (G+L)	.00	.00	.01	.00	.01	.00	.00	.00	.00	.00
Of Child	.04	.06	.13**	.09	.11*	.12*	.11*	.09	.05	.13*
R^2 (G+L+C)	.00	.01	.02*	.01	.01	.03*	.01	.02	.01	.02*
Composite										
During Gestation	.14**	.12*	.14**	.09	.11*	.02	.04	−.01	.04	.05
During Lactation	.09	.12*	.12**	.12*	.03	.08	.01	.02	.01	.09
R^2 (G+L)	.02**	.02*	.02**	.02*	.01	.00	.00	.00	.00	.01
Of Child	.11*	.10	.19**	.10*	.13**	.07	.15**	.03	.08	.11*
R^2 (G+L+C)	.02*	.02	.04**	.02	.03**	.01	.03**	.00	.01	.02

*$P < .05$; **$P < .01$

measures. Furthermore, we are at a loss to explain some of the findings. For example, it is puzzling that the effect of nutrition is greater for language, essentially a nondynamic cognitive variable, than for memory which requires focused attention and cognitive strategy. Finally, and most important, we may be accused of not having measured all of the dimensions of the child's social environment and that, if we had done so, the amount of variance explained by nutritional measures after forcing social measures in first would have been substantially reduced.

The INCAP evaluation, despite costs and implementation difficulties in undertaking large-scale field studies, should be followed by additional research in order to deal with some of its problematic issues. Nevertheless, the analysis persuasively suggests that there is a causal linkage between nutrition and cognition competence. Follow-up of children into school and efforts to validate the cognitive tests by obtaining indigenous rankings of intellectual performance demonstrate that the test measures are not idle scores. Children with higher cognitive composites do better, attend school in greater proportions,[18] and are ranked as more intelligent by adults in the villages in which they live.[26]

There are a number of plausible explanations for the relationship between nutritional status and cognitive development. Either a lack of adequate total calories or a deficiency of protein may impede the development of the neurological system. Another possibility is that the poorly nourished child, pre- and post-partum, has insufficient energy to take advantage of opportunities for social contacts and learning. Finally, it may be that adults and older children treat the larger child as a more mature individual, which leads to increased social learning opportunities. Clearly, the state of knowledge in neither the nutritional nor the social sciences is sufficient to suggest a single, primary explanation.

It bears emphasis that the findings do not diminish social environmental explanations of difference in cognitive functioning. The generally persistent correlations between the social factor variables and cognitive functioning support the reasonableness of various views about the consequences of deficient family milieux. Moreover, the fairly systematic findings on the amounts of variance explained by nutritional and social measures from one cognitive dimension to the next suggest that the social and nutritional inputs into a child's life have different magnitudes of importance in determining performance on various cognitive dimensions.

Nevertheless, as we noted in our 1977 preliminary report, at least in rural Guatemala, nutrition intervention programs are relatively easy to implement in comparison to most other social action efforts. In terms of the human and economic resources required for broad-scale, sustained social milieu interventions, and the political and cultural barriers to their rapid implementation, there is sound reason to stress nutrition intervention efforts in the formulation of social and community development policies for rural Guatemala—and perhaps for other lesser-developed countries as well.

REFERENCES

1. Brozek J (ed): Behavioral effects of energy and protein deficits. Proceedings of the International Nutrition Conference, November 30–December 2, 1977. National Institute of Arthritis, Metabolism, and Digestive Diseases, DHEW, NIH Pub. No. 79-1906, August 1979.
2. Chase HP, Lindsley WFB, O'Brian D: Undernutrition and cerebellar development. Nature 1969; 221:554–555.
3. Dobbing J: Effects of experimental undernutrition on the development of the nervous system. IN: Scrimshaw NS and Gordon JE (eds): Malnutrition, Learning and Behavior. Cambridge, MA: MIT Press, 1968, pp 181-203.
4. Barnes RH, Moore AU, Pond WG: Behavioral abnormalities in young adult pigs caused by malnutrition in early life. J Nutrition 1970; 100:149-155.
5. Dobbing J, Smart JL: Clinics in Development Medicine. London: Heinemann Radical Publications, 1972.
6. Behar M: Prevalence of malnutrition among preschool children in developing countries. IN: Scrimshaw NS and Gordon JE (eds): Malnutrition, Learning and Behavior. Cambridge, MA: MIT Press, 1968, p 30.
7. U.S. Department of Health, Education, and Welfare, National Center for Health Statistics: Height and Weight of Children: Socioeconomics Status. Vital and Health Statistics Series 11- No. 119. DHEW Pub. No. (HSM) 73-1601, 1972.
8. Cabak V, Najdanvic R: Effect of undernutrition in early life on physical and mental development. Archives of Disease in Childhood 1965; 40:532-534.
9. Cravioto J, DeLicardie ER, Birch HG: Nutrition, growth and neurointegrative development: An experimental and ecologic study. Pediatrics 1966; 38:319-372.
10. Monckeberg F: Effects of early marasmie malnutrition on subsequent physical and psychological development. IN: Schrimshaw NS and Gordon JE (eds): Malnutrition, Learning and Behavior. Cambridge, MA: MIT Press, 1968, pp 269-278.
11. Stoch MB, Smythe PM: Undernutrition during infancy and subsequent brain growth in intellectual development. IN: Scrimshaw NS and Gordon JE (eds): Malnutrition, Learning and Behavior. Cambridge, MA: MIT Press, 1968, pp 278-289.
12. Hess RD: Social class and ethnic influences on socialization. IN: Musse PH (ed): Carmichael's Manual of Child Psychology, Vol. 2. New York: Wiley, 1970, pp 457-559.
13. Evans DE, Moodie AD, Hansen JDL: Kwashiorkor and intellectual development. S A Med J 1971; 45:1413-1426.
14. Klein RE, Freeman HE, Kagan J, *et al*: Is big smart? The relation of growth to cognition. J Health and Social Behavior 1972; 13:219-225.
15. Klein RE, Read MS, Riecken HW, *et al* (eds): Evaluating the Impact of Nutrition and Health Programs. New York, NY: Plenum Press, 1979.
16. Klein RE, Irwin M, Engle PL, Yarbrough C: Malnutrition and mental development in rural Guatemala: An applied cross-cultural research study. IN: Warren N (ed): Advances in Cross-Cultural Psychology. New York: Academic Press, 1977, pp 92-121.
17. Klein RE, Arenales P, Delgado H, *et al*: Effect of maternal nutrition on fetal growth and infant development. Pan American Health Organization Bulletin 1976; 10:301-306.
18. Irwin M, Engle PL, Yarbrough C, *et al*: The relationship of prior ability and family characteristics to school attendance and school achievement in rural Guatemala. Child Develop 1978; 49:415-427.
19. Freeman HE, Klein RE, Kagan J, Yarbrough C: Relations between nutrition and cognition in rural Guatemala. Am J Public Health 1977; 67:233-239.
20. Mejia-Pivaral V: Caracteristicas economicas y socioculturales de cuatro aldeas ladinas de Guatemala. Guatemala Indigena, Vol. VII, No. 3, Instituto Indigenista National, Guatemala, 1972.
21. Rossi PH, Freeman HE, Wright SR: Evaluation—A Systematic Approach. Bevery Hills, CA: Sage Publications, Inc., 1979.
22. Monckeberg F, Tisler S, Toro S, *et al*: Malnutrition and mental development. Amer J Clin Nutr 1972; 25:766–772.
23. Lechtig A, Habicht JP, Delgado H, *et al*: Effect of food supplementation during pregnancy on birth weight. Pediatrics 1975; 56:508-520.
24. Yarbrough C, Habicht JP, Martorell R, Klein RE: Physical anthropology and mild to moderate malnutrition: A definition of the problem. Wenner-Gren Foundations/Fels Research Institute, NY, 1974.
25. Klein RE, Lester BM, Yarbrough C, Habicht JP: On malnutrition and mental development: Some preliminary findings. IN: Chavez A, Bourges H, Basta S (eds): Nutrition, Vol. 2. Switzerland: S. Karger Basel, 1975, pp 315-321.
26. Klein RE, Freeman HE, Spring B, *et al*: Cognitive test performance and indigenous conceptions of intelligence. J of Psychology 1976; 93:273-279.

ACKNOWLEDGMENTS

This report, prepared as part of a program of collaborative research on Uniform Measures of Social Competence by H. E. Freeman, J. Kagan, R. E. Klein, and A. K. Romney, was supported by the National Science Foundation (Grant GS-33047).

ACOG to Host 1982 World Congress of Gynecology & Obstetrics

The American College of Obstetricians and Gynecologists (ACOG) will host the Xth World Congress of Gynecology and Obstetrics of the International Federation of Gynecology and Obstetrics (FIGO) from October 17-22, 1982, in San Francisco, California. FIGO is a federation of the national obstetric and gynecologic societies in 80 countries.

This will be the first time in 12 years that FIGO meets in the United States; it met in New York City in 1970. The average physician attendance is 5000, and many allied health personnel also attend.

For further information write the Xth World Congress of Gynecology and Obstetrics, c/o The American College of Obstetricians and Gynecologists, One East Wacker Drive, Suite 2700, Chicago, IL 60601, USA.