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Is Big Smart?
The Relation of Growth to Cognition

ROBERT E. KLEIN
Institute of Nutrition of Central America and Panama

HOWARD E. FREEMAN
Brandeis University and Russell Sage Foundation

JEROME KAGAN
Harvard University

CHARLES YARBROUGH
Institute of Nutrition of Central America and Panama

JEAN-PIERRE HABICHT
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Regardless of the statistical manipulations used to separate the independent contributions of physical growth and social factors to cognitive functioning, the two classes of measures remain co-related to mental development in a study group of Guatamalan rural children. The importance of growth and social factors, however, varies by cognitive domain, and there are also important differences by sex of the subjects.

AMONG investigators in developing countries—and in some cases among the indigenous populations that constitute the subjects of nutrition studies—the belief persists that "big is smart." Although scientists familiar with the work on nutrition and mental development are quick to indicate the serious methodological limitations of individual investigations, most believe that the cumulative research effort is persuasive of the notion that protein-calorie consumption directly affects the quality of cognitive functioning. This hypothesis is supported by investigations that have utilized different research strategies:

(1) Studies of animals suggesting that diets of poor quality contribute to impaired neurological development.
(2) Laboratory experiments in which food intake and diet are related to activity levels and learning performance in animals.
(3) Cross-sectional epidemiological studies of human populations that reveal correlations between indexes of physical growth and psychological test performance.
(4) Comparisons of clinically identified malnourished and normal children that show differences in both activity levels and intellectual status.

Most of the reports of empirical work, as well as a large number of review papers, argue that nutritional status is related to mental development Klein, et al. (1971); Pollitt (1969); Ricciuti (1970). Illustrative examples of investigations and abbreviated indications of their limitations are contained in Table 1. Given the problems of method and the logical constraints on causal inferences, there is good reason to remain skeptical about the nature of the association between nutrition and intellectual status.

But it is easy to overlook incomplete data and methodological defects in malnutrition studies. If feeding children makes them both healthier and more intelligent, the rational bases for extensive programs of nutritional improvement are strengthened. Scientists and policymakers alike can, in good conscience, support the continuation and expansion of dietary improvement efforts domestically as well as in economically less privileged nations.

However, the presumed causal relation between diet and intellect is challenged by the findings of numerous investigations of the influence of the social environment on the child's cognitive functioning. The Coleman report, as well as less ambitious but more rigorous investigations, provides support for the argument of an association

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TABLE 1. ILLUSTRATIVE STUDIES OF NUTRITION AND MENTAL DEVELOPMENT

Type	Investigators	Method	Limitations
Animal studies of neurological and brain development	Dobbing (1968) Chase, et al. (1969)	Biochemical and weight measurement of brain structure	Poor anatomical specificity and no direct test possible of relationship of structure and function
Laboratory Studies of food intake and behavior	Dobbing and Smart (1972) Barnes, et al. (1970)	Differential provision of diet and subsequent search for behavioral consequences	Difficult to extrapolate findings to higher mental functions in humans
Cross-sectional epidemiological studies of humans	Cravioto, et al. (1966) (No other major study)	Correlations between physical growth measures and same measure of mental performance	No or limited control of variables other than nutritional status that may cause difference in mental performance
Comparisons of clinically diagnosed cases of malnutrition and "normals"	Stoch and Smyth (1968) Witkop, et al. (1970)	Case and group comparisons between children with positive and negative histories of malnourishment	Limited control of other possible causal variables. Also inferences are limited to effects on extremely malnourished

between aspects of the social environment and cognitive development in children. Many psychologists contend that selected child rearing experiences and opportunities for learning affect the child's motivation to acquire knowledge, to perform well on tests, and to expand his reservoir of information.

The funding of extensive action programs, such as *Sesame Street* and *Head-start*, attest to the seriousness with which this competing view is held. Hence any effort to understand the relation between nutrition and mental development must acknowledge the potential contribution of the social milieu. Conversely, efforts to understand the role of early experience on cognitive function must acknowledge the potential influence of nutritional status on mental development.

The need to study both nutritional and social factors involves complex issues of design and analysis. The number of variables that must be either quantified or controlled requires respectable sample sizes and unwieldy information collation and data reduction programs. Further, the immature state of the nutritional and behavioral sciences does not permit complete solutions to some of the major problems of method. An extensive monograph could be written on this topic and some of these issues have been discussed in the various review articles previously referenced. For example:

(1) Disagreement over the meaning of intelligence and mental development has resulted in the construction of dramatically different tests of cognitive functioning.
(2) Measurement of social factors is seriously limited to brief periods of observation in the home or retrospective interviews with parents.
(3) The psychological and sociological measures are of questionable or limited reliability and the cultural relevance of particular variables is often ignored.
(4) There is no satisfactory operational definition of nutritional status, no way to assess the epochs of nutritional deprivation in a child, and little agreement on the critical age span that should be observed in prospective studies.

Although the data presented in this paper are more refined than those of many previous investigations, because of the opportunity to profit from past work, the multidisciplinary character of the project, the relatively large sample size, the careful de-

velopment of psychological measures, and access to extensive computational resources, it is still a preliminary report—with a message of caution.

Method

The subjects in this study are 3 to 6 year old Spanish-speaking children living in four isolated, rural villages in eastern Guatemala. They are part of a continuing longitudinal study of the relations among nutrition, physical growth, psychological performance and social experience.

This report considers three classes of variables—psychological test scores, physical growth indices, and familial social variables. The psychological and physical growth variables were collected within fifteen days of the child's birthday; the social variables at the beginning of the study. These three classes of variables, which were taken from larger domains, were selected because of their relevance to other studies and their satisfactory reliability. The reliability of the measures were generally assessed by test/retest procedures and meet acceptable standards (i.e., in general, in the .70–.80 range). All interview and test data were obtained by trained field assistants of the same language background as the subjects.

Nutritional data. The child's head circumference and total height are used here as indices of nutritional status. Both variables presumably reflect the child's history of protein-calorie intake, although genetic background and morbidity experience also may influence head size and height. Extensive field trials conducted as part of the program from which the data reported on here are drawn argue for the utility of anthropometric measures as indicators of nutritional status. In villages in which children receive an annual intake of more than 20 liters of high protein food supplement, children's physical growth velocities are similar to those recorded for children in the U.S. In villages not supplemented, these velocities are significantly lower.

Psychological measures. The three variables discussed were selected from a large battery; each was standardized with age-sex groups.

Language facility. This score is based on the child's ability to name and recognize pictures of common objects and to note and state the relations among orally presented verbal concepts.

Short term memory for numbers. The child's score is based on his recall of increasingly long strings of numbers read to him at the rate of one per second.

Perceptual analysis. The child's score is based on his ability to analyze complex visual arrays and to locate hidden figures embedded in a larger background or to detect which of several similar variations of an illustrated object was identical with a standard.

Familial social measures. These measures were developed to identify the position of the child's family within the social structure of the village. While these small subsistence farming communities are relatively "flat" in their stratification, differences in life style can be identified. The measures are part of a broad battery of scales developed to assess social status and differential environmental opportunities for maximizing cognitive development. Underlying the construction of the measures is the commitment to the general view that social stratification and interpersonal modeling are critical to the psychological development of children.

The scores are derived from observation and interviews with the children's mothers. Six variables are included here:

Quality of house: Rating based on the type of construction, interior design and quality of the dwelling.

Father's occupation: Rating based on store ownership and land possession.

Mother's dress: Rating based on whether or not the mother possessed particular items of commercially manufactured clothing.

Mother's hygienic practices: Rating based on the frequency of hand and face washing by mother.

Task instruction: Rating based on family members' reports of teaching the child to count, to perform household tasks and to travel to a nearby town.

Social contacts: Number of social contacts adult members maintain outside the home.

Results and Discussion

The analysis presented here focuses on the unique and joint contributions of physical growth and familial social measures to variation in psychological performance. To put the question simply: Is physical growth, as an index of nutritional history, related to cognitive functioning *independent of social environmental factors?*

The three psychological variables were considered separately since there are good reasons for suspecting that these dimensions might be differentially associated with environmental experience, and also perhaps with nutritional status. The conceptual independence of the three variables is supported by the findings of this study. The correlations among language, memory and perception scores ranged from .18 to .31, with most coefficients in the mid-twenties. These correlations, as well as the means and standard deviations were remarkably similar for all age and sex groups.

Physical growth and psychological performance. Table 2 contains the relation between physical growth and psychological test scores. Two values are presented for each association. The first value is the linear correlation coefficient; the second, noted in parenthesis, is the standardized beta weight from the multiple regression analyses of the physical growth and psychological measures. The latter values indicate the contributions of each growth measure to the variance in psychological score. Only variables that explained one or more percent of the variance are included in this and subsequent analyses.

Three important generalizations are implied by the data in Table 2: There is a marked sex difference in the magnitudes of the multiple correlations for memory and language. Physical growth is a better predictor of vocabulary and short term memory for *girls* than for boys. Further, the two growth measures correlate more uniformly across the three psychological dimensions for girls than for boys. For example, the linear correlations between height and each of the three psychological measures are .31, .28 and .20; the comparable values for boys are .16, .05, and .21. It should be noted that the mean standard deviations and reliabilities are similar for the sexes. Finally, the beta weights, which appear in parenthesis, suggest that the two growth measures are not simply redundant estimates of a single growth dimension, although head circumference accounts for more of the variance than height in most cases. This pattern of results may be the product of the changing relation of height to head circumference over age.

Familial social variables and psychological performance. A duplicate analysis for the six social measures is shown in Table 3. These data suggest several generalizations.

As with the growth measures, the social variables explain some of the variance in each of the psychological domains. The amount of variance explained ranges from

TABLE 2. RELATIONSHIP BETWEEN PHYSICAL GROWTH AND PSYCHOLOGICAL MEASURES BY SEX

	Psychological Dimension					
	Language		Memory		Perception	
	M	F	M	F	M	F
Height	.16 (.08)*	.31 (.22)	.05	.28 (.16)	.21 (.13)	.20 (.09)
Head Circumference	.23 (.20)	.29 (.19)	.18 (.18)	.33 (.25)	.31 (.27)	.32 (.28)
Multiple R	.24	.35	.18	.36	.33	.33
N	172**	170	114	114	101	.99

* Values in parentheses are standardized beta weights, i.e. the separate contribution of the variable to the multiple correlation. On this and Table 3, only the beta values for variables that explain one or more percent of the variance are shown.

** N's vary primarily because tests are applicable to different age groups.

TABLE 3. RELATIONSHIP BETWEEN FAMILIAL SOCIAL MEASURES AND PSYCHOLOGICAL PERFORMANCE BY SEX

	Psychological Dimension					
	Language		Memory		Perception	
	M	F	M	F	M	F
Quality of house	.25 (.11)	.20	.13 (.10)	.26 (.19)	.05	.07
Father's occupation	.17 (.11)	.22 (.11)	.06	.19 (.13)	.02	.00
Mother's dress	.30 (.23)	.26 (.21)	.01	.20 (.10)	.16 (.14)	−.12 (−.16)
Mother's hygiene	.03	.09	−.03	.02	.07	.02
Task instruction	.04	.31 (.23)	.15 (.12)	.09	.11 (.09)	.19 (.22)
Social contacts	.17	.07	.06	.12	.04	.11
Multiple R	.34	.39	.17	.30	.18	.25
N	175	170	147	114	101	99

* See notes below Table 2.

what most investigators would regard as "important" to magnitudes most would view as "trivial even if statistically significant." Second, the social measures are most predictive of language for both sexes and least predictive of memory and perceptual analysis. Third as with the growth variables, there are sex differences in the strength of the associations. The most persuasive instance occurs for memory, where quality of house, father's occupation, and mother's clothing are better predictors for girls than boys. The multiple R is .30 for girls but only .17 for boys.

The first three social variables in Table 3—quality of house, father's occupation and mother's dress—are commonly regarded as indicators of socioeconomic class. These three variables are intercorrelated (e.g. $r = .50$ for quality of house and mother's dress). These two variables, however, may reflect modernity as well as economic position in the community. Their predictive power with respect to language score is impressive, and consistent with a large number of studies of cognitive functioning in the United States and Western Europe.

Task instruction also predicts language score, especially in girls, perhaps because mothers spend more time with their daughters than with sons after age 4 or 5, and engage more often in cooperative and complemetary tasks with them. It is of course not possible to explain the variations in the magnitudes of all the coefficients and we will not strain to interpret each set of values.

Independent and joint contributions of physical growth and social measures to psychological performance. These data, like those of other studies, suggest that both physical growth and social factors are related to psychological performance. The final issue is whether any general statement can be made about the unique contribution of nutritional status to mental development, independent of social factors. Put another way, do the growth variables predict cognitive functioning after all the variance attributed to the social variables has been acknowledged?

The procedure was first to regress the social variables against the psychological measures and then to add the physical growth variables to see if they explain any additional variance. The variables selected were those that both accounted for two percent of the variance and had beta weights with associated p values of .20 or less. The results of this analysis are in Table 4.

The modest increases in the multiple correlations that include both sets of predictors, compared with the multiple correlations derived from either physical growth or social variables alone, suggest

that the nutritional measures to some extent reflect social dimensions and, correspondingly, the social variables are partial indicators of nutritional status.

The last row of Table 4 reports the proportion of the variance that height and head circumference (reflectors of nutritional status) contribute uniquely to the variation in cognitive functioning. These growth measures have the greatest explanatory power for the perceptual analysis tasks and more predictive power for girls than for boys.

Conclusions

Regardless of the statistical manipulations used to separate the independent contributions of physical growth and social factors to cognitive functioning, the two classes of measures remain co-related to mental development, albeit at a modest level. But there are two important qualifications that must be added.

First, the magnitude of the associations between either growth or social measures and psychological performance vary markedly by cognitive domain. Second, there are major sex differences in the magnitudes of the correlations between either growth or social factors and psychological performance. Investigators who study the relation of nutrition to mental development often make the implicit assumption that the psychological sequelae of protein-calorie malnutrition should be similar for males and females and typically do not analyze their data by sex. Since this assumption is biologically defensible; the presence of sex differences in the data imply that social factors are mediating the relation between malnutrition and mental development. That is, the interaction effects between nutritional and social determinants of cognitive development may be different for boys and girls, particularly in communities studied where cultural representations are markedly sex segregated including child rearing practices and evaluation of various cognitive skills. It should be noted that some of these sex differences may be sampling variations. We cannot claim that they definitely exist, although they occur repeatedly in our data. Given the widespread existence of known sex-related differences in both physical and psychological development the findings are not surprising and we believe the sex differences are real.

The sample contains adequately nourished children and ones whose level of nutritional insult ranges from severe to mild with the vast majority of the malnourished subjects in the mild to moderate range. The terms "mild" and "moderate" are used with trepidation since precise measurement of nutritional; status is not possible except with extensive longitudinal data. As noted previously, a large number of the group are below height and head circumference norms. Our food supplementation studies suggest the deficiencies are diet related. Few of the children, however, have had sufficient nutritional insult to be clinically identifible as severely malnourished. These findings do not bear on the assertion that severely malnourished children with clinically observed apathy and poor moti-

TABLE 4. MULTIPLE CORRELATIONS OF PHYSICAL AND SOCIAL MEASURES WITH PSYCHOLOGICAL MEASURES AND INDEPENDENT CONTRIBUTIONS OF PHYSICAL MEASURES TO MULTIPLE R

	Psychological Dimension					
	Language		Memory		Perception	
	M	F	M	F	M	F
Multiple R— Physical measures alone	.24	.35	.18	.36	.33	.33
Multiple R— Social measures alone	.34	.39	.17	.30	.18	.25
Combined Multiple R of physical and social measures	.39	.47	.20	.40	.36	.41
Proportion of explained variance accounted for by physical growth measures	.20	.30	.50	.56	.80	.92

vation have depressed cognitive scores. This study is concerned with persons who vary in adequacy of diet, but not with the relatively rare case of extreme malnutrition.

A number of criticisms can be addressed at this analysis. We are aware of the validity problems surrounding the variables selected. Even with the strenous efforts to develop reliable variables, the unreliability that remains has an unknown effect on the results. We recogize that the social measures are metrically inelegant and we have not met all of the statistical assumptions required for some of the analyses performed. Additional indices of either physical growth or social characteristics could have been included and may have modified the findings. Finally, the two physical growth variables are not sensitive indexes of either the severity, duration, or age at onset of nutritional insult. Hence the nutritional heterogeneity of the groups may account for some of the findings.

Some of these limitations may be overcome when the prospective longitudinal experiment, from which these data are drawn, is completed. In the experiment, two of the four communities under study are receiving a dietary supplement; the other two exist on a normal dietary regimen. We hope it will be possible to study changes in nutritional status and to estimate, with social factors taken into account, the association between protein-calorie intake and cognitive development.

Any serious consideration of alternative large scale action programs awaits this more definitive longitudinal analysis. Possibly then we will be able to answer with more confidence the question: "Is big smart?" The only proper reply at the moment is, "Perhaps, but it depends . . ."

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