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MALNUTRITION, MENTAL DEVELOPMENT, BEHAVIOR AND LEARNING

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MALNUTRITION, MENTAL DEVELOPMENT, BEHAVIOR AND LEARNING

Joaquin Cravioto, M.D., M.P.H., D.Sc.
Professor and Scientific Director
National Institute of Child Health
Sciences and Technology - DIF
National System for the Comprehensive
Development of the Family

Through the creation of society and of culture and of the concomitant development of technology, man who initially was only a biological species has developed into a flexible and changing social organism. Because of his capacity to learn and his ability to think, man can act consciously and establish rules and laws of behavior for protecting the social organism, even against forms of behavior produced to satisfy the biological demands of some of the individuals that make up society, if the need arises. The ability of man to reason enables him to determine what to do with himself and with the environment he lives in. In addition to his physical and biological environment, man, as a social entity, has

This revision is taken from the paper by Cravioto et al for the book entitled "Human Growth" edited by Falkner and Tanner. It should not be distributed except as a working document to the members of the PAHO Advisory Committee on Medical Research (ACMR).
a social environment that embraces all kinds of transactions, present or potential, that occur whenever a human being encounters, by chance or deliberately, another human being.

Within this social context man has become interested in the fate of his species. Specifically during the last half of the twentieth century, growing interest has been focused on the various ways in which the environment can affect man. Health has become a focus of attention for a steadily growing number of persons and institutions connected with the planning and implementation of economic, social and cultural development policies. A logical outcome of this behavior has been the thought given to the role that nutrition can play in the life of the individual from the time he is conceived until the time he dies, especially during the period of his growth and maturation.

In our time, all of us, both experts and laymen, agree that the consumption of a sufficient amount of good quality food is a crucial factor in the life of man and that, in that of the child, it is virtually a prerequisite for optimum growth and development. It is not too much to say that nutrition is perhaps the all-pervading factor that affects the health and well being of man.
Nevertheless, Jose Maria Bengoa in a study of nutritional conditions in 12 countries in Latin America, four in Asia, and eight in Africa, found that millions of children were suffering from various degrees of malnutrition. This expert in nutrition has also pointed out that we should realize that although, on first sight, nutrition is contingent upon factors in the physical environment such as climate, topography and geological structure, and the biological components of the human environment represented primarily by food chains, the all important determinant of the nutritional status of the population is the social milieu in which it develops. In the final analysis, nutrition, good or bad, is part and parcel of the total context of social, economic and cultural conditions.

It, therefore, follows that malnutrition at the community level is a problem created by man and is especially prevalent in those segments of the population that have little or no say in the decisions taken about economic, social and political matters. In these population strata, the present system, consciously or unconsciously, created malnourished individuals, generation after generation, through a number of mechanisms; foremost among them are limited access to goods and services, little social mobility and restricted opportunities to receive and use experiences in critical moments of their life. As a result, malnutrition is a
very common disease among the "vulnerable groups" made up of older weaned and preschool-age children and pregnant women or nursing mothers, since, in addition, these groups need more nutrients and energy foods.

In the control of malnutrition as in the control of any other fatal disease, survival was the primary objective. A better knowledge of the differences in the homeostatic responses to harmful agents characteristic of malnourished individuals, as opposed to well-nourished individuals, the detailed and quantitative description of the chemical pathology of the malnourished and the availability of better methods and techniques for early diagnosis and the treatment of electrolytic disturbances and infection were capable of reducing the case fatality rate in children suffering from severe malnutrition; so that the probability of dying or surviving which 20 years ago was 50% has, since 1962 to date, become less than 5% for preschool-age children treated in pediatric wards.

Despite this spectacular breakthrough it must be borne in mind that the problem of malnutrition in children does not end when a low case-fatality rate has been achieved. It is precisely the fact that most of the malnourished, even the severe malnourished, do not die and that, in the pre-industrial world, millions of adults have suffered at least one episode of malnutrition during their
childhood that makes it imperative to endeavour to investigate the consequences of early malnutrition for mental development, learning and behavior at later ages.

Approaches to the Problem

The strategies research workers have used to study the consequences of malnutrition have been derived from their conceptualization of malnutrition in man. One group considers malnutrition to be an acute disturbance that is rather well delimited in time. This concept led to the conduct of filed studies such as those of Hiernaux in Rwanda (1964), to experiments on human volunteers like the outstanding study of Keys et al (1950) and studies like those of Richardson in Jamaica (1976), which endeavour to quantify the contribution of malnutrition as acute symptoms. Another group considers malnutrition to be a chronic process that may or may not be acutely exacerbated both by physiological conditions and the social circumstances of the individual at risk (Dean 1950, Gopalan 1955).

Three additional approaches have been used to endeavour to clarify the causal factors and the consequences, both short and long term, of protein-calorie malnutrition. These three approaches have been used to study the organism at full development, since it has been demonstrated that, in the adult, the consequences of
malnutrition are transitory (Keys, et al, 1950) whereas the young have proved to be very vulnerable and to suffer damage that may be permanent (Jackson and Steward, 1920, Platt et al, 1964). With this focus of attention, the three principal strategies developed are as follows: 1) the deprivation model; 2) the intervention model; and 3) the ecological or natural history model. The research studies carried out with these strategies have included case studies, comparison of populations, an analysis of special conditions of risk, replacement and rehabilitation.

The deprivation model, used especially in experiments with laboratory animals, has been extremely useful since it has made it possible to examine the impact of malnutrition on various biological structures by using controlled conditions that it would be impossible or immoral to obtain in human beings. This strategy has provided data on specific organs, systems and mechanisms of biological organization exposed to the process of malnutrition.

Despite their very important contributions, studies on laboratory animals do not provide a complete analogy with human conditions. Laboratory animals lack the social substratum in which the deprivation of man takes place and with which he interacts. Furthermore, the impact of malnutrition on behavior must
be limited in the animal model to relatively simple types of behavioral adaptation that can be exhibited by the lower animal so that the effects that malnutrition might have on social functions and complex behavioral patterns cannot be reproduced in the analogue which, although very useful, is a supplement and not a substitute for the studies that should be made on human beings.

The approach based on intervention represents the other face of the coin of deprivation; with this model a research worker seeks to estimate the combined effects of nutrition, infection and social and family circumstances by systematically changing each one of the variables he considers important. In practice, this has resulted in the differential application of food supplements, control of infectious diseases, improvement of housing, increase in the level of formal or specific education in health and nutrition, economic subsidies to increase income, and an increase in opportunities for social learning in communities or population samples supposedly comparable in all the factors to which they are not subject to intervention.

The principal attraction of the intervention model is its attempt to separate the influential variables and to compare them in a way similar to that used in laboratory experiments in physics or chemistry. Unfortunately, it is extremely difficult to exactly
match groups and to prevent the dissemination of the effect when subsegments of one and the same population are handled differently. The assumed homogeneity even of small and relatively isolated populations is only an assumption (Cravioto et al, 1967) so that while the use of different communities reduces the dissemination of the effect, it increases the difficulty of comparability. In any event, to the foregoing we must add the fact that every time a variable is affected, there is danger of an ecological rearrangement, especially when the variable acted on is food, since we must not forget that food and nutrition are precisely central foci of human organization.

Although the intervention model raises problems of ethics; for example, when the intervention is food supplementation in which the principal problem is the recognition that that supplementation will, for most of the cases, end when the study period ends. The effect of this supplementation on the ecology of the food with undesirable consequences when its availability and consumption is ended is something that cannot be overlooked. Of course, it may be argued that these are moral considerations and not strictly methodological considerations and that if they are anticipated as part of the total design, the transition can be made without prejudice to the population involved.
The third model is the ecological approach. This is in fact a special form of the method known as the natural history method and is intended to determine the nature of the influential variables through the study of their interrelations in one and the same population. When this method is applied to the problem of malnutrition, the intention is to separate patterns of cause and effect by seeking the interrelations between nutrition, health and social factors over time.

Use of the ecological model over a sufficiently long period makes it possible to identify age-specific risk conditions, to relate causes and consequences in different periods or stages of development of the individual, and to set up scales of biological and social time. Levels of macro or micro-environment may be selected by the research worker to ascertain the interaction of his biological and social variables. The point to be recognized in this model is that the factor he is studying is precisely the uncontrolled variation; therefore, the basic requirement for its use is the existence of sufficient variability in the factors to be considered in the community it is intended to study.

The major problem of the ecological approach is the multiplicity of factors to be measured and the quantification of many of the family and social variables involved.
In this chapter through a review of selected investigations we have attempted to present, in summary form, the current status of our knowledge on the relationship between malnutrition and mental development and learning.

I.- SOME OF THE PROBLEMS INVOLVED IN THE ASSESSMENT OF THE ROLE OF MALNUTRITION.

In attempting to assess the role that malnutrition may have on mental functioning of the human, it becomes essential to consider the meaning of food and feeding along at least three dimensions. The first one, is the physiological dimension which has as a unit of measurement the nutrient or the joule, and whose function is to provide chemical substances to the organism for purposes of growth, maintenance and metabolic regulation.

The second dimension of food may be considered as psycho-physical. Its unit of measurement would be the foodstuff which through its organoleptic characteristics would provide the organism with a variety of stimuli (texture, color, aroma, taste, temperature, etc). In this context, a foodstuff presented at the table as two different kitchen preparations having the same nutrient and energy content would, in fact, behave as if two different foods were offered to the individual.

Finally, the third food dimension may be considered as psychosocial in nature. Its unit of measurement would be the
mealtime. The functions of food along this line are, on the one hand to aid in symbol formation through the value family and society attach to food, such as a form of reward or punishment, as an experience attached to a gratifying person, or as an identifying characteristic of an ethnic or subcultural group. On the other hand, the meal time provides opportunities to demonstrate, clarify and practice role and status at the family and at the community level. Who is waited on first? Who sits at the place of honor at the table? Who receives the best part of a dish? Who moderates conversation at the table?, are some examples of the way in which this food dimension is expressed.

It seems easy to visualize that food deprivation in young children represents not only a shortage of nutrients necessary for the increase in mass of the infant, but also a deprivation of sensory stimuli and of social experiences.

The very fact that malnutrition at the community level can be considered as a man-made disorder characteristic of the underprivileged members of society, particularly of the pre-industrial societies where the social system, consciously or unconsciously, produces malnourished individuals generation after generation through a series of social mechanisms among which limited access to goods and services, limited social mobility, and restricted opportunities for social stimuli and experiences at crucial times in life play a major
role, makes it difficult to determine the contribution which malnutrition vis a vis all the other potential conditions of risk for maldevelopment may be making to the inhibition of growth in mental abilities. The problem increases its complexity because of the varying degrees to which the central nervous system is vulnerable to insult at different ages (Chase et al., 1967, Benton et al., 1966, Davison and Dobbing, 1966, Dobbing, 1963). These investigators have reported species differences in the age of most rapid myelination, and for the species exposed to food restriction have documented the relation of abnormal outcomes in central nervous system structure and composition to the conjunction of malnutrition and the time of most rapid growth and differentiation of the nervous system. Accordingly, not only the presence of malnutrition but the time of life at which it is experience must be taken into account if the relation between exposure and mental performance or learning adequacy is to be properly assessed.

The time factor has another important bearing on the problem of malnutrition and development. The assessment of the developmental consequences of malnutrition suffered during infancy or the preschool years cannot be fully evaluated at the time of the insult. This is particularly true when one wishes to quantify the effects of malnutrition on such functions as intellectual abilities, school achievement, and later social and economic competence. For the assessment of these late effects, a considerable gap in time must elapse between the
period of exposure and the period in which the functions to be evaluated can be examined meaningfully. It is apparent that this gap in time allows the potential intervention of many which may influence the course of the child's developing competence. Thus, for the effect of the nutritional condition to be assessed, the influence of these operating factors must be accounted for.

Nonetheless, the gap in time between the exposure to malnutrition and the assessment of complex nervous system activities is an asset in itself. Clearly, the effect of malnutrition on the developing nervous system is unlikely, except in rare cases, to be fully manifested by changes in simple reflex and adaptive behaviors. Many years ago, Lashley (1929) demonstrated that as much as 20 percent of the rat cerebral cortex could be extirpated without demonstrable consequences for simple maze learning. However, Maier (1932) using the same species showed that as little as 3 percent of destroyed tissue demonstrably affected more complex learning performances. Thus lags in developmental differentiation or even distributed lesions, produced in the nervous system by malnutrition would be expected to manifest themselves at varying distances in time from the age of the primary insult. At these latter ages, when more complex demands for integration are made, opportunities for increased sensitivity in the assessment of consequences exist. A time gap in the assessment of consequences therefore is essential if the full force of the potential insult is to be measured. However,
the existence of a time gap does make it necessary to know and to account for the influence of social and other variables on the course of development during the intervening period.

In dealing with the problem of protein-calorie malnutrition in humans and its effects on mental function, investigators have not tended to approach the issue neuro physiologically. Rather than explore the question of the impairment of mechanisms of brain functioning which may result from deficient nutritive intake they have attempted to answer the practical question of whether the more readily noted reductions in somatic growth and biochemical maturation are associated with reduced mental performance. Further, they have wished to know whether such mental lags, when they have been found, represent permanent changes in functional effectiveness or are merely transient phenomena which disappear with nutritional recovery.

II. - SENSORY-MOTOR DEVELOPMENT IN MALNOURISHED INFANTS.

In several regions of the world where malnutrition in early infancy is highly prevalent a direct association between deficits in height and weight of severely malnourished preschool children and lags in psychomotor, adaptive, language and social-personal behavior, as measured by the Gesell, Catell or Bayley methods, has been reported by Geber and Dean (1956) in Uganda children, Robles et al. (1959) and Cravioto and Robles (1962) in Mexican children,
Serial studies on sensory-motor development in kwashiorkor patients have shown that as recovery from malnutrition takes place, developmental quotients, which are extremely lower than those obtained in non-malnourished children of similar age and social class, increase in most patients and the gap between normal age expectation and the actual performance of the child progressively diminishes for all except infants whose age on admission for treatment is less than six months. When developmental quotients are plotted against days of hospitalization it is apparent that the rate of behavioral recovery varies in direct relation to age at which malnutrition occurred. The older the group the greater the value of the slope (Cravioto and Robles 1962, 1965).

Research conducted in infants recovering from nutritional marasmus has also disclosed that intelligence and psychomotor activity, as judged by the Bayley Scales, remain severely retarded despite a clear somatic recovery. (Pollit and Granoff 1967). The results of these studies in kwashiorkor and marasmic patients have been confirmed in South Africa by Stoeh and Smythe (1963); in Chile by Monckeberg (1968) and Kardonsky et al. (1971) in Lebanon by Bothe-Antoun et al. (1968) and Yatkin and McLaren (1970), in the U.S.A. by Chase and Martin (1970), and in Brasil by Marcondes et al., (1969). All these reports point out the fact that children
affected with either marasmus or kwashiorkor exhibit marked retardation in sensory-motor development which is still present even after physical and biochemical rehabilitation have occurred.

Not only in general measures of mental development do malnourished children show a poorer performance. Brockman and Ricciuti (1971) have examined a more specific cognitive function, categorization behavior, in relation to malnutrition in twenty severe marasmic children and in 19 control children matched for age and sex, without a history of malnutrition and with heights above the tenth percentile of the Boston, U.S.A., norms. Using simple sorting tasks it was found that the total test scores on categorization behavior of the malnourished children were significantly lower than those obtained in the control children. On retest after 12 weeks of treatment the malnourished children showed no significant increase in scores. Analysis of the ten individual sort tasks differences disclosed not only lower performance levels for the malnourished children than for the controls, but also appreciable less variation among task differences. Children with a longer period of successful treatment expressed as greater gain in body length and head circumference, and with a higher clinical rating of nutritional recovery tended to perform better on the cognitive tasks.

All the above-mentioned studies make it clear that even after a period of several months children who had made a successful
nutritional recovery of severe malnutrition and are medically considered as cured still show developmental lags not only in psychomotor behavior but also in several other areas, including hearing and speech, social-personal behavior, problem-solving ability, eye-hand coordination, and categorization skills.

III.- EARLY MALNUTRITION AND INTELLIGENCE AT SCHOOL AGE.

Follow-up studies of children, who as infants have suffered from severe malnutrition requiring hospitalization, constitute one of the model systems through which research workers have assessed the degree to which severe malnutrition in early life may affect subsequent levels of intelligence. In order to minimize the possibility that the period of hospitalization might itself have continue to exert a depressing effect on performance, the assessment of level of functioning must be conducted in survivors several years after discharge from the hospital. Within this model two main strategies have been used. The first one compares the intelligence test performance of children with documented episodes of severe malnutrition with the performance of children living in the same community, but without antecedents of severe malnutrition. Since malnutrition develops in environments conducive, in many ways, to lower performance investigators have tried to match survivors of early malnutrition with control children for those non-nutritional variables considered as capable of playing and important role.
The second strategy involves the comparison of children who have experienced early severe malnutrition with their own sibs raised in the same family environment but not experiencing the same severity of nutritional insult. The assumption behind this strategy is that siblings as controls cancel out the majority of the demographic or macro-environmental variables leaving those related to the specific micro-environment of each child within his or her own family to be accounted for by other means or study.

Table 1 shows the main characteristics and results of the studies which have contrasted survivors of severe malnutrition and non-severely malnourished children drawn from the general population among which the cases of malnutrition have contemporaneously occurred. As may be seen these reports deal, in total, with children living in markedly different cultural settings, with geographical representations from Europe (Yugoslavia), Asia (India, Indonesia and the Philippines), Africa (Uganda), and Latin America (El Salvador). Survivors of malnutrition were tested several years after they were considered as cured. Intelligence test performance was assessed by a variety of tests either standarized for the country or specially designed for the particular study. The comparison groups were drawn from the population and risk. In the majority of the studies survivors and controls were only matched for age and general socioeconomic status at the time of retesting; two exceptions are the study of Champakan, Srikantia and Gopalan (1968) in which the
comparison group was matched for age, sex, religion, caste, socioeconomic status, family size, birth order, and educational background of parents with the survivors of severe malnutrition; and the study of Hoorweg and Standfield (1972) in which the comparison group was made up of children with records of good nutrition and growth during their first two years of life.

Srikantia, Sastry and Naidu (1975) have reported on the follow-up of the group of survivors of kwashiorkor whose mental performance at school age had been previously described in 1968 by Champakan, Srikantia and Gopalan (1968). Eleven years after discharge from the hospital the means in the Wechsler test were 49.9 for the experimental boys and 60.5 for the control boys; for girls the scores were 35.7 and 50.0 respectively for experimental and control groups. In the two year period that followed, the control boys had improved their score by 17.5 ± 4.05 points while the experimental boys had improved theirs by 22.0 ± 2.94 points. Similarly, control girls had improved their performance by 14.2 ± 1.4 points and the experimental by 18.1 ± 4.39 points. The differences in mean increment between the groups were not statistically significant, although both at the beginning and at the end of the observation time period the absolute scores were higher in the control groups, and more markedly so in boys. In other words, differences in I.Q. initially present in survivors of kwashiorkor and in control children persisted after a
lapse of over 13 years, but the early episode of severe clinical malnutrition did not alter significantly the subsequent rate of growth in intellectual performance.

The results of the six reported studies show that the presence of an episode of severe malnutrition occurring early in life and of enough severity to force the family to take the child to a hospital significantly increases the chances of survivors, years after discharge, of scoring at values much lower than those obtained in the children of the comparison groups.

Two studies on the effect of early malnutrition on intellectual performance at later ages have used the sibling strategy. In the first one, conducted in Mexico (Birch et al. 1971) measured intelligence at school age was compared in thirty seven survivors of severe malnutrition and in thirty seven of their siblings closest in age. The malnourished children all had been hospitalized for severe chronic malnutrition of the kwashiorkor type when they were between six and thirty months of age. No cases of marasmus were included, and the group was relatively homogeneous both for severity of illness and for type. All children had been discharged to the family following nutritional rehabilitation. The average time of hospitalization was six weeks, with a range of one to two months. During the hospital stay children were visited by their mothers for a three-to four-hour period every other day. The ratio of nursing staff to children was
high, with one nurse available for every three children. Care in hospital in general was good and considerate, but no special stimulation procedures were applied.

No detailed data were available with respect to the quality of the diets received by the children after their discharge from the hospital. Although it would be appropriate to assume from knowledge of the social circumstances in which the children lived that such diets were suboptimal, in no cases were any of the children ever readmitted to any hospital for severe malnutrition.

At follow-up the children were between five and thirteen years of age. In all cases intellectual evaluation was carried out at least three years after discharge from the hospital. The child chosen as the control was the one in the surviving sibship nearest in age to the index case and without any prior history of an incident of severe malnutrition. The age distributions of the index cases and of the sibling controls were very similar. This was the consequence of the sibling closet in age tending to be randomly older or younger than the index case. Sex distribution was somewhat divergent with relatively more females in the control cases. Difference in sex ratio, however, was no significant (chi-square=1.95; p more than 0.10).

At follow-up each child was individually examined to determine
intellectual level. The test used was the Wechsler Intelligence Scale for Children (WISC) in its Spanish adaptation. Although it was recognized that this test lacks sensitivity for the youngest children studied, it was judged desirable to use it for all children rather than to substitute a different and probably noncomparable test for the youngest age group.

Full scale WISC IQ of the index cases (sexes combined) was 68.5 and of the controls 81.5. Verbal and performance differences were of similar magnitude and in the same direction. All mean IQ differences were significant at less than the 5 percent level of confidence. If an IQ score of below 70 is considered a customary cut-off point for the definition of mental retardation, then twice as many of the previously malnourished children as their siblings functioned below this level; eighteen malnourished, compared with nine of the control subjects, had an IQ below 70. Moreover, of those with a low IQ, ten of the index cases were below 60, contrasted with only two of the control subjects. At the other extreme of the distribution, in the conventionally normal range, the reverse picture obtains: ten of the control subjects, compared with four of the index cases, had an IQ of 90 or higher. Differences in age between the survivors of malnutrition and their siblings did not affect the differences in intellectual test performance between the two groups. No significant sex difference in IQ was found among the rehabilitated children. The mean full scale IQ for boys and girls,
respectively, was 70.7 ± 14.08 and 68.6 ± 13.83.

The situation in the sibs group was different. In these children there was a significant difference between boys and girls, with the boys having significantly higher full scale and verbal IQ than the girls. When patients and control subjects were compare separately by sex it was found that the previously malnourished boys differed from the control boys significantly, with control subjects having a full scale IQ approximately 12 points higher than patients. Although control girls also had somewhat higher IQ than girls who were previously malnourished the size of the difference was insufficient to result in statistical significance. This pattern of finding was entirely the result of the depressed level of IQ in the girls in the control group. No reasons for this depression could be found in differing educational experience since there were no sex differences in school attendance. A depressed level of IQ in girls relative to boys, however, has been repeatedly found in children of school age in the social groups considered and probably derives from the far lower value attached to the education of girls in this particular subculture. (Cravioto, Lindoro, and Birch 1971).

When the scaled scores on the 11 subtest of the WISC obtained in the survivors of malnutrition were compared with the values found in the siblings, the analysis of the subtest profiles suggested a relative uniform depression of performance in the index cases with respect to a variety of cognitive demands.
In the second study using siblings, Hertzig, Birch, Richardson and Tizard (1972) decided to investigate the degree to which children malnourished before two years of age differ from their sibs and classmates in intellectual competence at school age. The index cases were 74 Jamaican boys who had been treated in a hospital for severe malnutrition before the age of two years. The three main clinical types of severe protein-calorie malnutrition—kwashiorkor, marasmic, and marasmic-kwashiorkor—were represented. Children on the average were hospitalized for a period of eight weeks. Follow-up visits in the homes by nurses were carried out for 2 years after discharge. At the time of the intelligence testing the children's age ranged from 6 to 10 years. This age range was selected in order to be far enough removed from the time of hospitalization, and for the children to be at an age where intelligence test performance has predictive value.

A sib and a classmate or yardmate were selected as controls for each index case. Two comparison groups were thus included, the first one made up of male sibs. For a sib to be selected he had to be between 6 and 12 years old, nearest in age to his malnourished brother and without a history of severe malnutrition. The second comparison group was made up of classmates or neighbors of the index cases. For index children attending school two male classmates closest in age to the index case were selected. If the first comparison child was not available for examination, the second comparison was used. Some of the index boys, though of school age,
were not going to school. For these cases, a comparison case was chosen by finding the nearest neighboring child who was not a relative and who was of an age within six months of the index case. For some index cases at small schools no classmate was within six months of age. For these cases neighbor children were also used as comparisons. As would be expected from the method of selecting comparison children, index and comparison children lived in the same general neighborhood from which the school drew its pupils.

Each child's intellectual level was individually evaluated by means of the Wechsler Intelligence Scale for Children (WISC). All children were examined without the examiners being aware of the group to which the child belonged.

Results showed that mean Verbal, Performance, and Total (Full Scale) Intellectual Quotients were lower in the survivors of severe malnutrition, with sibs scoring at an intermediate level, and classmates and yardmates having the mean highest scores.

Since the WISC Test has a floor of 46 points for both the Full Scale and the Verbal Scale, and of 44 points for the performance Scale, it is apparent that even if a child's responses were all wrong his minimal intellectual quotient would be the floor value, and therefore a comparison of mean IQ's would be inappropriate. With this in mind, Hertzig et al. compared the number of survivors of severe malnutrition and of control children who scored at the lowest
level of measurable performance. Twenty-three percent of the survivors against seven percent of the controls were at the floor level for the Full Scale I.Q. Similar results were obtained for the Performance Scale with no significant difference in the Verbal Scale. This analysis clearly shows the very low levels of I.Q. present in the survivors of severe malnutrition. In interpreting the data, it is of importance to note that no age trend for I.Q. was found in the study groups; nor was ordinal position for sibs responsible for the differences obtained.

The use of siblings as comparison subjects has certain implications for the interpretation of findings. Such comparisons are of course advantageous in that children who are contrasted come from the same families and tend to share a common experiential ambience. Demographic data, however, strongly points out that having a child hospitalized for severe clinical malnutrition in fact identifies a family in which all children are at risk for significant mild-moderate malnutrition on a chronic basis. Therefore, index cases and sibs are similar in sharing a common exposure to subnutrition on a life-long basis and differ, in this nutritional background, only in that the index cases have a superimposed episode of acute exacerbation. Consequently, the comparison of sibs and index children does not provide a full picture of the overall effects of nutritional inadequacy on intelligence performance. Rather, it indicates the additional consequence for maldevelopment which may attach to the superimposed
episode of acute exacerbation. The use of sibs as controls also means that the children compared have shared a generally disadvantageous social and family environment several features of which can in themselves significantly contribute to the depression of the intellectual performance levels. This factor, too, should result in the minimizing of differences between survivors of severe malnutrition and their sibs and provides further support to the significance of the difference found on measured intelligence.

In spite of their limitations, all the reviewed studies clearly show that the environment in which children at risk of malnutrition live is highly negative in its effects on mental development. Irrespective of the presence or absence of a previous admission to a hospital because of severe malnutrition, children developing in this milieu have a high probability of showing poor performance on intelligence testing. The presence of a superimposed episode of malnutrition occurring early in life, and of enough severity to force the child into a hospital, increases the chance of scoring at values even lower than those characteristic of the poor environment.

It must be emphasized that the finding of an association between early malnutrition and lower mental development is by no means evidence that the insufficient intake of nutrients and energy *per se* affects intellectual competence in man.
IV.- EARLY MALNUTRITION AND INTERSENSORY ORGANIZATION.

Since data from comparative psychology (Maier and Schneirla 1935, Birch 1954) and evolutionary physiology (Voronin and Guselmikov 1963) have suggested that the emergence of complex adaptive capacities is underlain by the growth of increasing liaison and interdependence among the separate sense systems, and in addition a variety of studies (Birch and Bitterman, 1949, 1951) indicated that the basic mechanisms involved in primary learning (i.e. the formation of conditioned reflexes) is probably the effective establishment and patterning of intersensory integration, Cravioto et al. in Guatemala and Mexico (1966, 1967), Champakan, Srikantia and Gopalan in India (1968), and Wray in Thailand (1975) in trying further to explore the mental functioning of school-age children who had been at various degrees of risk of malnutrition in the preschool years, have measured the development of intersensory integration in the kinesthetic-visual, kinesthetic-haptic, and haptic-visual modalities. The selection of these intersensory modalities was made on the basis of the work of Birch and Lefford (1964) who found that in normal children between the ages of six to 12 years the interrelations among three sense systems—touch, vision, and kinesthesia—improved in an age-specific manner and resulted in developmental curves that were as regular as those for skeletal growth.

In the Indian study, children rehabilitated from kwashiorkor,
suffered between the ages of 18 to 36 months, were compared at the age of 8 to 11 years with matched controls. Intersensory organization was poorer in the index cases that in the control subjects with differences highly significant. When these children were again tested 5 years later, the differences between the two groups had considerably decreased. Although the survivors of severe protein-calorie malnutrition still committed more errors than the control children the difference was not statistically significant. After another period of follow-up of two years, the performance of both groups of children was errorless.

The apparent catch-up of the nutrition rehabilitated group has to be taken cautiously. When applying a test with a clearly developmental course the point at which the asymptotic performance is reached might be the only difference between a group with normal development and a group with a developmental lag. If a child has already completed the maximal level of performance and another child obtains that same level later in time, although both children have now the same score it cannot properly be said that the second child caught-up with the first. Moreover, in societies were the demands are chronological-age specific the importance of a lag in development might be fundamental for the future role and status of those affected inspite of the fact that later in life, such as in adulthood, the test performance of these individual may not differ at all from that obtained in their more fortunate mates.
In the Mexican, Guatemalan and Thailand studies school-age children aged 5 through 11 years tested. According to the physical growth achievement at each age level the lower quartile of height distribution (most stunted children) and the upper quartile of the distribution (most fully grown children) were contrasted in their intersensory abilities. Differences in neurointegrative skills were manifested in all combinations of intersensory integrations examined. Tall children, particularly in the younger age groups, performed at a higher level of competence than stunted children, Figures 1 to 3 illustrate the results of the Guatemalan study. Not only were mean differences significant, individual variability in performance also tended to be greater in the shorter children. Obviously, when height is used as an index of risk of exposure to prior malnutrition at least 3 contaminating variables must be controlled in interpreting its association with levels of performance. The first is that height differences should not merely be the reflection of familial differences in stature; the second, that short stature should not be just another manifestation of a general developmental lag; and the third, that shorter children must not come from familial environments at significantly lower socio-cultural levels.

These non-nutritional factors were ruled out as main contributors to the results obtained since: 1) height of parents and children were
not significantly correlated: 2) No significant association was found between the height of the fathers and the level of intersensory competence achieved by the child; 3) Tall and short children of the same age in populations of children without antecedent conditions of nutritional risk did not exhibit differences in their levels of intersensory adequacy; and 4) by the lack of correlation between height and income, occupation, housing, personal cleanliness, presence of sanitary facilities in the home, and contact of parents with mass communication media. Educational level could not be eliminated as an important intervening variable since mother's level of formal education was significantly associated with her child's height. Accordingly, The Guatemalan, Mexican and Thailand results could be interpreted in the sense that the inadequacy in intersensory development could represent the effects of earlier malnutrition in association with more general subcultural differences between the tall and short children.

A more detailed definition of the roles of malnutrition and cultural factors obviously requires a prospective study of a community of children with varying quantified risk of malnutrition in infancy and during the preschool years.

More recently, we have had the opportunity of a preliminary analysis of the visual-kinesthetic development in children with known nutritional histories during their first seven years of life.
As may be seen in figure 4, the competence level at 78 months of age in survivors of severe malnutrition suffered before 3 years of age in markedly lower than performance obtained in children from the same birth cohort who never had severe malnutrition. When the survivors of malnutrition were matched with non-malnourished for total stimulation available in the home, as measured by the inventory of Bettye Caldwell (1967), figure 5 show the persistence of the lower levels of competence in the children with the previous history of severe malnutrition.

The reports of neurointegrative adequacy in 4 different cultural settings (India, Guatemala, Thailand and Mexico) may be significant because they suggest that functional lags could occur at mild-moderate degrees of protein-calorie malnutrition, and may not be limited to the extremely severe cases represented by kwashiorkor and marasmus.

Trying to extend our inquiry to other types of cross-modal integrations, two studies of auditory-visual equivalence were carried out. The first one in the school children of a Mexican rural area where malnutrition in early life is highly prevalent (Cravioto, Gaona-Espinosa, and Birch 1967). All children aged seven through twelve were weight and measured, and on the basis of height achievement the lower quartile and the upper quartile of the
distribution at each age were compared in their auditory-visual performance. The children's ability to integrate auditory and visual stimuli was individually tested by a method of equivalence in which the children were asked to identify visual dot patterns corresponding to rhythmic auditory patterns (Birch and Belmont 1964).

At each age level the mean performance of the taller group was higher than that of the shorter. The difference was most striking at age twelve, when 42 percent of the taller children were making eight or more correct judgements, with 30 percent achieving a perfect score of 10. In contrast, only 9 percent of the shorter children in this age group achieved scores of eight or greater, with none making a perfect score.

In the second study (Cravioto, 1971) the developmental course of auditory visual equivalence was studied in 39 school-age children who had suffered severe clinical malnutrition before the age of 30 months, and in 39 siblings of similar sex and age. When the performance of siblings and index cases was contrasted, age by age the survivors of severe malnutrition were well below their siblings in auditory-visual competence.

Independently of whether intersensory organization is interfered
by malnutrition per se or through one or more of the variables which produce or accompany malnutrition, neurointegrative development is delayed in those children at nutritional risk who have grown poorly. It is, therefore important to consider the potential significance of this type of developmental lag in so primary a process as intersensory organization for more complex psychological functioning. In this connection it is of interest to consider two significant features: learning-conditioned reflex formation and acquisition of academic skills.

In most conditioning situations what is being demanded is the integration between two stimuli, each of which belongs to a different sensory modality. Thus, in classical salivary conditioning of a leg withdrawal, a gustatory or a tactile stimulus is in effect being linked to an auditory or visual one. The process of conditioning, when effective, therefore involves the establishment of intimate equivalence between initially nonequivalent stimuli in different sensory modalities. If interrelations among sensory modalities are inadequately established the possibility exists that conditioning will either be delayed in its occurrence or that the pairing of stimuli will be ineffective in producing conditioned reflexes. Therefore, failure for intersensory integration to occur at normal age-specific points can contribute to inadequate primary learning at the given age level.
Evidence already exists that the lag in the development of certain varieties of intersensory integrations have a high correlation with backwardness in learning to read or to write. In this respect, Birch and Belmont (1964, 1965) and Kahn (1965) have data strongly suggestive that backwardness in reading is significantly associated with inadequacy in auditory-visual integration. Data are also available that point out the dependence of visual-motor control in design-copying on visual-kinesthetic intersensory organization. (Birch and Lefford 1967). Since the time of Baldwin (1897) it was recognized that such visual-motor control is essential for learning to write, therefore, the lag in intersensory organization can interfere with a second primary educational skill - learning to write.

Thus, inadequacies of intersensory development can place the child at risk of failing to establish an ordinary normal background of conditionings in his preschool years and at the risk of failing to profit from educational experience in the school years.

V.- VISUAL PERCEPTION.

An essential prerequisite for learning to read is the child's ability to distinguish simple visually presented figures, and to respond to more differentiated aspect of the figural percept such as angular properties and spatial orientation. Failure to respond to these aspects can result in the child confusing the letters which
in the Roman alphabet are identical in form but distinguishable by
their spatial positioning. Lower case letters such as b, p, d, and
q, or capital N and Z, W and M, all represent equivalent shapes with
the distinction among them depending upon the child's ability to
respond simultaneously to shape and to orientation in visual space.

Using the visual discrimination task developed by Birch and
Lefford for their studies on voluntary motor control (1967) visual
perception of forms was explored in 39 school children who had been
treated for severe malnutrition at ages below 3 years, and in an
equal number of their nearest age and same sex siblings. Age by age,
the levels of performance of recognition of geometric forms although
low for both groups of children were significantly lower for the
survivors of severe malnutrition until age 9 years when both
siblings and previously malnourished children achieved similar levels
of competence, with the circumstance that this asymptotic performance
level had been reached by the siblings since age 7 years.

When the children were tested for their ability to analyze
geometric forms, the mean number of errors committed also decreased
as age advanced. Once again a marked difference was found in favor
of the siblings. Thus, survivors of severe malnutrition present a
lag in readiness to read which is even lower than the low readiness
characteristic of their low socioeconomic class (Cravioto, DeLicardie,
Piñeiro, and Alcalde, 1969).
VI.- LANGUAGE DEVELOPMENT.

In the course of a longitudinal ecological study of a total cohort of children born during one calendar year in a rural village of central Mexico out of the 334 infants inducted 14 girls and 8 boys developed clinically severe protein-calorie malnutrition before the age of 5 years. Fifteen of the 22 patients developed kwashiorkor the other 7 marasmus. Ten children, 6 with kwashiorkor and 4 with marasmus, were treated at home, while 9 children with kwashiorkor and 3 with marasmus were treated in a pediatric hospital. No deaths occurred in the latter group, but 3 of the 10 children treated at home died.

These cases occurred despite the fact that all children in the cohort studied were medically examined on a biweekly basis. Children who failed to grow normally were indentified, their infectious illnesses were treated, and their parents were given advice (which they did not follow) on the appropriate feeding and management of children who failed to thrive. In contrast to its lack of influence on the incidence of clinically severe PCM, this medical attention decreased the infant mortality rate from a figure of 96 per thousand to 46, and reduced the preschool mortality of the cohort by one-half. Incidentally, these data point out, once more, that traditional medical care can strongly influence mortality with minimal or no effect on morbidity.
Since one of aspects being under investigation in the cohort was language and communication, it was possible to analyse its development prior, during, and after the episode of severe malnutrition. In a first report, Cravioto and DeLicardie (1972) have described language development and appearance of bipolar concepts in the group of survivors of severe malnutrition in comparison with a group of children selected from the same birth cohort who were never diagnosed as severely malnourished and who were matched, case by case at birth, for sex, gestational age, season of birth, body weight, body length, and performance on the Gesell Test.

During the first three years of life language acquisition was evaluated by means of a technique similar to the Gesell (Gesell and Amatruda, 1947). Mean language development was very similar in index cases and controls during the first year of life when only one case of severe malnutrition had been diagnosed. As time elapsed and more children became ill with severe malnutrition a difference in language performance favorable to the matched controls became evident. The difference was more pronounced at each successive age tested. Not only were mean values significantly lower in the index cases, the distribution of individual scores was also markedly different. At 1080 days of life 11 of the 19 control children had language scores above 1021 days-equivalent. As a contrast, while none of the children in the malnourished group scored
above 960 days-equivalent, 12 of the 19 cases had values below 720 days, with 3 of these children exhibiting language development inferior in more than six months to that observed in the control children who had the lowest scores.

Since the emergence of the conception of opposites and with it bipolar labeling represents an early and readily measured aspect of the development of concepts in young children, and since concept development and particularly the emergence of verbal conceptions, have long being viewed as a basic factor in the development of human intelligence, the natural acquisition of bipolar concepts was assessed in the longitudinal cohort of children starting at 26 months of age.

Data obtained by Rojano (1970) in the total cohort of Mexican children tested at successive ages with the series of bipolar concepts developed by Francis H. Palmer at the Institute for Child Development and Experimental Education of the City University of New York, U.S.A., for the systematic training and enrichment of language experience, documented a clearly developmental course of competence in response to tasks involving the utilization of such bipolar concepts as a scale of progressive difficulty. The test could be used with young children less than 3 years of age because most of the items included only require the selection by the child of an object representing a given pole (e.g. big-little: long-short: 
in-out; black-white) from two objects differing only with respect to their position on one of the concepts continua. The items are grouped into two forms so that each form contains items covering both poles of each concept. The forms differ only with respect to the setting in which the concepts are placed. The score derived from the test provides a measure of the child's knowledge of various categories that are commonly used in organizing sensory experience.

Since examination of bipolar concept acquisition were done in the total cohort at twenty-six, thirty-one, thirty-four, thirty-eight, forty-six, fifty-two, and fifty-eight months of age, it was possible to compare the patterns of competence of this function in the group of children who developed severe malnutrition and in their selected controls, both at the time some of children were suffering from severe malnutrition and after they had been nutritionally rehabilitated.

The mean number of bipolar concepts present in the children with present or past severe malnutrition was significantly lower than the mean number of concepts shown by the control group. The differences at all ages but age thirty-one months were statistically significant. Not only were mean values significantly higher in the control children, the proportion of better performers was also higher. Thus, for example, at 26 months of age while almost one-half of the control children had 5 or 6 concepts, none of the malnourished
subjects had attained this level of competence. On the other hand, one out of every three malnourished children had a maximum of one concept while seven out of every ten controls are at the level of two or more concepts. Even after nutritional rehabilitation the survivors continued to lag behind the controls. Thus, at age 58 months four out of every ten survivors had not more than 17 concepts while the minimum number shown by the control children was 18 concepts. Similarly, none of the previously malnourished children had more than 20 concepts while two out of every ten controls were above this level. A study of increments at successive ages showed that between ages 26 and 38 months, the period in which the last cases of severe malnutrition appeared, increments in the control group were far greater than those in the malnourished group. During rehabilitation the survivors of severe malnutrition had an increment twice as big as that of controls: unfortunately, at later ages the increments tended to be lower, and there was not enough time for the previously malnourished children to catch-up. In other words, the lag in language development present when the children were actually malnourished continued to persist after clinical recovery had taken place.

Since the group of malnourished children had significantly lower scores in home stimulation than the control children, in an attempt to separate the possible influences of stimuli deprivation from those of malnutrition an analysis of the interrelations among these two variables and the number of bipolar concepts was carried out. As a first approach to this issue a technique of partial correlation was employed in order to estimate the degree of association
between two of the variables "holding constant" the influence of third variable. Since the number of severe clinical malnutrition is rather small, it was decided to test for the interrelations in the total birth cohort assuming that body height is a good indicator in the community under study, of the risk of chronic malnutrition.

The coefficients of correlation product x moment among home stimulation scores, total body height, and number of bipolar concepts present at 46 months of age in the total cohort were all significant at no less than 0.05. When the relation between home stimulation and number of bipolar concepts was partialed out for body height the coefficient of correlation dropped from 0.20 to 0.15. When the relation between body height and number of bipolar concepts was partialed out for home stimulation the coefficient changed from 0.26 to 0.23; finally when the number of bipolar concepts was "heald constant" the coefficient of correlation between home stimulation and body height changed from 0.23 to 0.19.

These results suggest that the association between home stimulation and number of bipolar concepts is mediated, to a good extent, through body height which in turn holds a significant degree of association with the number of bipolar concepts independently, to a large extent, of home stimulation. Within the limits of the probabilities given by the magnitude of the coefficients, home
stimulation contributes relatively more to body height than to
number of bipolar concepts while body height contributes more than home
stimulation to the variance of bipolar concepts.

VII.- STYLES OF RESPONSE TO COGNITIVE DEMANDS.

Since the studies on the possible effects of malnutrition on
mental development and learning in humans have, for the most part,
focused on achievement without considering behavioral style, DeLicardie
and Cravioto (1973) decided to analyze, as a part of their longitudinal
study on the effects of environment on mental development, the
modification that an episode of severe malnutrition might make on
the behavioral style of lower class children. In other words, they
were concerned not with how well but with how the children with
antecedents of severe malnutrition behaved. To answer this question
the strategy for the analysis focused on the comparison of
responsiveness to cognitive demands in 14 survivors of severe clinical
malnutrition suffered before thirty-eight months of age, and in two
groups of children selected from the same birth cohort who never
showed signs or symptoms of severe malnutrition and who were matched,
case by case, with the survivors. In one comparison group the
matching was done for sex, gestational age, season of birth, body
weight, total body length, and organization of the central nervous
system as determined by the Gesell method. The second comparison
group included fourteen children, full-term and healthy at delivery
who were matched for sex and IQ (WPPSI) at five years of age with the survivors of severe malnutrition.

At the age of 5 years, all children were individually examined using an adapted version of the Wechsler Preschool Primary Scale of Intelligence (WPPSI). The tasks of this test were used to obtain behavioral information on response style to a standardly presented set of cognitive demands. During the administration of the test a detailed protocol of the child's behavior and verbalization was recorded by an independent observer.

The analysis of response styles followed the logic tree developed by Hertzig et al. (1968). When confronted with a demand, a child can respond either by working or not working. This initial choice can be expressed through either verbalization or motoric action. If the choice was to work, whether verbally or non-verbally, the response can involve an expression of spontaneous ideational extension or it could be delimited and restricted to the defined requirements of the task. In relation to non-work responses the different styles can be expressed as simple negation, substitutive behavior, request for assistance, or as a rationalization with respect to competence when the starting point is verbal. If the non-work response is nonverbal the subdivisions are simple negation, substitutive behavior, request for assistance, or passive unresponsibleness. All categories, in terms of which response styles to cognitive demands are classified, are objective generalizations about observed behavior.
As Hertzig and co-workers have emphasized, the categories are not, nor are they intended to be, inferences about the underlying reasons for the expression of the observed behavioral patterns.

Since the logic classification of styles is done mainly through a series of dichotomies, the way for identifying individual differences in the responsiveness to cognitive demands consisted in ascribing a child to a particular style when his proportion of responses of that style was equal to or greater than 0.75. Table 2, shows the main style of response in survivors of malnutrition and controls.

It is apparent that while survivors and controls for IQ and sex tend to be similar in their styles of response the children in the group of controls matched at birth showed a different style. Verbal behavior predominated among this letter group, and the children who were classified as of the not-work type had verbal competence as their main style of response. Conversely, among the survivors and the controls matched for IQ and sex all the not-work children were of the not-work-nonverbal type, unresponsiveness being the typical behavior of these not-work children. Moreover, controls for size at birth when they give not-work verbal responses these are mainly expressed in terms of competence rationalizations.

In the presence of these findings, one might tend to consider
that the differences in patterns of response between the controls matched at birth and the survivors of severe malnutrition could be explained on the basis of differences in intellectual performance. The observation of similar behavioral patterns in children with and without antecedents of severe malnutrition but with equal low intellectual performance would be in favor of this explanation. Moreover, Hertzig et al. (1968), in their study of middle-class American and working-class Puerto Rican children, found that differences in IQ affected the proportion of demands that was met by a work response, the proportion of total responses that were verbally expressed, and the style of verbal not-work. However, the difference in styles observed between middle-class and Puerto Rican children persisted at all IQ levels. Lugo (1971) in a study of urban Mexican children of three different social classes, also found a quantitative difference in responsiveness as a function of IQ level, but the differences in response style persisted across the socioeconomic levels in the presence of a common IQ range. Accordingly, one cannot accept differences in IQ as the reason for differences in behavioral patterns of response.

Besides the I.Q. difference between survivors of malnutrition and controls matched for size at birth, home stimulation scores, assessed by the inventory of Caldwell (1967) were significantly higher in the controls matched at birth, with similar low scores
in both survivors and controls matched for I.Q. and sex. This difference in stimulation could significantly contribute to the development of dissimilar patterns of responsiveness, particularly in relation to the amount and type of verbalization.

In attempting to tease out the effects that may be due to malnutrition from those which may be due to stimuli deprivation, survivors of severe malnutrition and controls with equal scores in home stimulation were identified. Ten controls for I.Q. and sex, seven survivors of severe malnutrition, and six controls for size at birth met this requirement. When the styles of response of these children were compared no difference was found among the three groups in the mean number of total responses, in the proportion of work responses, in the proportion of total responses verbally expressed and in the styles of nonverbal non-work responses. On the other hand, the proportion of verbal not-work responses observed in controls matched at birth (0.87) was almost three times the proportion found in either survivors (0.30) or controls matched or IQ and sex (0.26). The difference between controls matched at birth and the other two groups was significant at the level of confidence of 0.001.

When the styles of verbal not-work responses were compared, it was observed that the three groups were markedly different. Controls matched at birth expressed their verbal not-work responses in terms of rationalization of competence, survivors expressed their responses
mainly as request for aid, and controls matched for IQ and sex had similar proportions of styles of competence, requests for aid, and substitution.

The finding of unresponsiveness as a characteristic style in children who with or without antecedents of severe malnutrition have as a common background a low level of home stimulation leads one to consider that regardless of a physiological component that may be present when the children were malnourished, the passive behavior of survivors of severe malnutrition is probably linked to stimuli deprivation.

The differences observed between survivors of severe malnutrition and controls with equal scores of home stimulation seem to indicate that besides the effect of stimuli deprivation on the styles of response, the antecedent of clinical severe malnutrition appears to be another influential factor.

It has been suggested by Canosa, Solomon, and Klein (1973) that differences in performance between well-nourished and malnourished children may be due to a lower ability of the malnourished subjects to or concentrate on the given task. However, since these children have a high frequency of passive responses when confronted with a demand, failure to perform efficiently could be a consequence of this style of behavior. For example, any task requiring systematic
scanning or elaboration of information by progressively more complicated steps requires the child to engage actively in the pursuit of an answer. Unresponsiveness as a style of behavior may lead to a quick answer without regard for its accuracy. Similarly children with passive patterns of behavior may give low scores on tasks that are penalized for time.

VIII.- INFLUENCE OF AGE AND DURATION OF MALNUTRITION ON LATER PERFORMANCE.

Dobbing (1976) through a masterly series of studies has documented his concept of the developing brain's vulnerability. According to this concept there is a pathology of brain development in which the timing of etiological factors in relation to the growth spurt sequence is of even more significance than their duration and their severity. Moderate growth restriction, which before the brain growth spurt or afterwards does not leave traces of pathology, results in permanent structural and functional alterations when it occurs at the time when the brain is passing through the period of most rapid increase in weight.

In accordance with this concept, age at the time of insult and duration of the period of malnutrition, or rather of growth restriction, becomes of the greatest importance in relation to the prognosis. The general hypothesis would be that the effect of severe postnatal malnutrition, capable of significantly restricting
somatic growth, would vary as a function of the period of life at which the lag in growth was experienced.

To test this hypothesis Cravioto and Robles (1965) examined the mental recovery of twenty Mexican Infants hospitalized for kwashiorkor. On admission for treatment six infants were below 6 months of age, 9 between 15 and 29 months, and 5 between the ages of 37 and 42 months. All children were tested with the Gesell method at regular intervals of 2 weeks. As recovery from malnutrition occurred, developmental quotients increase in most of the patients and the gap between normal age expectation and the actual performance of the child progressively diminished for all except those in the group whose age on admission was less than 6 months. These younger malnourished infants showed no tendency to "catch up" and increased in developmental age only by a figure equal to the number of months they remained in the hospital. Serial data on performance plotted against days of hospitalization showed that the older the group the greater the value of the slope.

Hoorweg and Stanfield (1972) selected from their records in Uganda three groups of children aged 11 to 17 years who had been treated for severe clinical malnutrition suffered before 27 months of age. Each group consisted of 20 former patients whose ages when admitted for treatment were less than 16 months for group one, between 16 and 21 months for group two, and between 22 and 27 months
for those included in group three. General intelligence, verbal abilities, spacial and perceptual abilities, visual memory, short-term memory, learning and incidental learning, and motor development were evaluated. Significant differences among groups were found in Memory for Designs in which group 3 performed better than groups one and two, and in the learning task in which group two did better than group one. In two other tests, incidental learning and short-term memory, the differences as a function of age at which malnutrition was treated reached a significant level of confidence of 0.10. The findings are in the expected direction in which those children who suffered younger do more poorly.

Intelligence Quotients, derived from a battery of tests that included Raven Progressive Matrices, the Koch Test, and the Goodenough Draw-a-man Test, were found significantly associated with the age on admission for treatment of severe malnutrition in a group of fourteen survivors examined nine to eleven years after discharge from a hospital in El Salvador, Central America (Guillen-Alvarez, 1971).

Chase and Martin (1970) in the U.S.A., did a follow-up study of nineteen infants who were hospitalized at less than one year of age because of severe undernutrition. Forty-two months after discharge from the hospital the mean Developmental Quotient obtained with the Yale Revised Developmental Examination was significantly
lower than the Quotient found in a comparison group of children matched for birth date, weight, sex, race and socioeconomic status. Children admitted to the hospital with severe malnutrition lasting longer than the first 4 months of life gave the lowest quotients on the follow-up. All the children admitted in the first 4 months of their lives had 3 1/2 years later Developmental Quotients above 80, whereas 9 of 10 children who had suffered malnutrition for periods longer than their first 4 months of life had Developmental Quotients below 80. These findings are in line with a report of DeLicardie et al. (1971) who found that a group of infants who, for no detectable reason, had body weights at 15 days of life below their birth weight continued to weight less than their matched controls throughout the first year of life and lag behind in total body length, head circumference, chest circumference, arm circumference and braquial skin-fold thickness without exhibiting a significant difference in their mental development, assessed by the Gesell Technique. Along this same line of age and duration, Stein and co-workers (1975) in their brilliant epidemiologic study of the Dutch famine did not find a relation between the mental performance of young men at the time of their military induction and their prenatal exposure to famine. Since no evidence could be found of interaction of prenatal famine exposure with indicators of social environment that might had influenced compensatory learning opportunities and promoted better subsequent mental development, and also no evidence was found that selected survival might had masked or
distorted an association of prenatal famine exposure with mental performance at the age of military induction, it appears as if deficient food intake confined to the prenatal period may be either of too short duration to produce a detectable effect on mental performance on the young adult or the insufficient nutrient intake period was out of phase with the brain's growth spurt, that for the human starts around mid-gestation but has its maximal rate postnatally and extends its duration at least well into the second year of life. (Dobbing, 1974).

Hertzig and associates (1972) in their study of Jamaican school-age boys who had suffered from severe malnutrition before age two, did not find a significant correlation between age of the child at the time of admittance for treatment and Wechsler Intelligence Quotient. When the I.Q.'s of the 74 children were divided into those belonging to the children admitted for treatment before 8 months of age, between 8 and 12 months, and between 13 and 24 months, an analysis of variance showed that the means for the subgroups were not statistically different at the 5% level of confidence. Since Hertzig's data show very clearly that I.Q. mean values in the survivors of malnutrition are misleading due to the significant number of children who scored at the floor level of the Wechsler, before accepting the author's conclusion of no relationship between time at which severe malnutrition occurs and severity of
mental outcome it might be convenient to test for performance differences in their age groups using non-parametric statistical techniques.

Klein, Forbes and Nader (1975) in 50 children, 44 boys and 6 girls, aged from 5 to 14 years who had been treated for congenital pyloric stenosis estimated the severity of starvation as the percentage difference of infant's weight on admission for treatment and expected weight for age, extrapolated from birth weight. General intelligence, measured by the Peabody Picture Vocabulary Test and the Raven Progressive Matrices Test, showed a significant correlation with the estimated degree of starvation ($r=-0.323$, p less than 0.05). The scores on a scale that measures the parental evaluation of the child's intellectual development and expected educational potential also correlated significantly with the severity of starvation ($r=-0.367$, p less than 0.01). These data apparently are at variance with the study of Berglund and Rabo (1973) who did a follow-up of 174 Swedish boys who suffered from inanition, starting at ages 6 to 20 days, because of pyloric stenosis. After a variable period of starvation during which body weight became lower than birth weight the patients recovered. A significant correlation between height at adulthood and weight loss and duration of starvation in infancy was found, but the performance on an intelligence test, administered at the time of registration for military service, did not correlate with the history of malnutrition in infancy.
Even considering the limitations inherent to the types of studies reported it seems apparent that severity, duration, and particularly the time at which the malnutrition insult occurs are relevant factors in determining the permanency or transiency of the physical and mental after effects. It must be remembered at all times that nutritional deprivation may constitute just another of the numerous factors present in the impoverished environment in which infants and children develop malnutrition.

IX.- MECANISMS OF ACTION OF MALNUTRITION.

It must be emphasized that the finding of an association between early malnutrition and lags in mental development and learning, and distortion in behavior is by no means evidence that the insufficient intake of nutrients and calories per se affects intellectual competence, learning and behavior in man. In attempting to explain the effect of malnutrition on intellectual competence and learning at least two possibilities can be entertained. The first and simplest hypothesis would be that the nutrient deficiency affects mental functioning by directly modifying the anatomical and/or biochemical structure of the central nervous system. In favor of this explanation it is relevant to remember that increase of cell cytoplasm with extension of axons and dendrites (one of the processes associated with the growth of the brain in early life) is largely a process of protein synthesis. From the microspectrographic investigation
of the regenerating nerve fibers it has been estimated that protein substance increases more than 200 times as the apolar neuroblast matures into the young anterior horn cell. In experimental animals specific amino acid deficiencies can cause structural and functional lesions of the central nervous system (Scott 1964). In mice, inhibition of protein synthesis in the brain produced by puromycin is accompanied by loss of memory (Flexner et al. 1962). Delays in myelination and reduction in cell number and in cell distribution in the brain caused by interference with adequate nutrition in early age have been amply documented (Dobbing, 1968; Winick and Rosso 1969; Chase, Dorsey, and McKhann 1967; Benton, Moser and Dodge, 1966; Davison and Dobbing, 1966; Dobbing, 1974; Guthrie and Brown, 1968; Kerr et al. 1976; Winick 1969; Winick and Noble, 1966). Preliminary findings of reduction in brain size and even in cell number in children who died with severe malnutrition have been reported from Mexico (Ambrosius 1961), Uganda (Brown 1965), and Chile (Winick 1969; Winick, Rosso, and Waterlow 1970). In this respect Stein, Susser and Saenger (1975) have rightly pointed out that even autopsy at death cannot prove the irreversibility of the brain cell depletion reported in fatal cases of early malnutrition nor indeed can be inferred from these studies whether the depletion is compatible with life and even to be found in survivors.

In regard to functional changes link to inadequate diets Barnes et al. (1968, 1970) and Frankova and Barnes (1968) have documented in rats and pigs a series of disorders including learning
disability, and Platt et al. (1964) have reported electro physiological changes in various animal species.

The second hypothesis considers that malnutrition in human children does not need to produce structural lesions of the central nervous system to affect intellectual competence behavior and learning. Three possible indirect mechanisms can be postulated:

1. Loss of learning time. Since the child was less responsive to the environment when malnourished, at the very least the child had less time in which to learn and had lost a certain number of months of experience. On the simplest basis, therefore, the child would be expected to show some developmental lags.

2. Interference with learning during critical periods of development. A considerable body of evidence exists indicating that interference with the learning process at specific times during its course may result in disturbances in function that are both profound and of long-term significance. Such disturbance is not merely a function of the length of time the organism is deprived of the opportunities for learning. Rather, what appears to be important is the correlation of the experiential opportunity with a given stage of development. It is possible that exposure to malnutrition at particular ages may in fact interfere with development at critical
points in the child's growth course and so provide either abnormalities in the sequential emergence of competence or a redirection of the developmental course in undesired directions.

3. **Motivation and personality changes.** It should be recognized that the mother's response to the infant is to a considerable degree a function of the child's own characteristics of reactivity. One of the first effects of malnutrition is a reduction in the child's responsiveness to stimulation and the emergence of various degrees of apathy. Apathetic behavior in its turn can function to reduce the value of the child as a stimulus and to diminish the adult's responsiveness to the child. Thus, apathy can provoke apathy and so contribute to a cumulative pattern of reduced adult-child interaction. If this occurs it can have consequences for stimulation, for learning, for maturation, and for interpersonal relations, the end result being significant backwardness in performance on later more complex learning tasks. It has been reported in experimental animals that small but statistically significant differences in the size of the cerebral cortex can be obtained by manipulation of the stimulatory aspects of the environment (Diamond et al. 1966). Recently (Castilla-Serna, Cravioto, and Cravioto 1973) we have reported the synergistic effects of malnutrition and stimuli deprivation on the biochemical structure of the brain, confirming and extending the findings of Levitsky and Barnes (1972) on the affects of nutrition and isolation on animal behavior. Cravioto and DeLicardie in a study on the environmental correlates of severe malnutrition (1972) found that none of the
characteristics of parents (biological, social or cultural) or family circumstances (including income per capita, main source of income and family size) were significantly associated with the presence or absence of severe malnourishment. On the other hand, mother's listening to the radio and level of stimulation available in the home help substantially to differentiate families with or without severely malnourished children. These microenvironmental characteristics, as well as an inadequate mother-child interaction (Cravioto and DeLicardie, 1974), were present a long time before the appearance of the severe episode of malnutrition.

Klein and co-workers (1972) have shown that in children rehabilitated from malnutrition body height and head circumference increase the level of prediction of cognitive function over and above the prediction level given by socio-cultural factors such as quality of house, father's education, mother's dress, mother's personal cleanliness, task instruction, and social contacts. Richardson (1976) has reported that the I.Q.'s of Jamaican school age children who suffered severe clinical malnutrition before age 2 years were significantly associated with the presence or absence of severe malnutrition as such, with total body length at the time of intelligence testing, and with a measure of the child's social background. These studies point out the importance of the environment as a synergistic factor both in the development of early malnutrition and its consequences.
Research work in experimental animals leads in the same direction. Thus, Barnes and his group on the basis of their results from a long series of animal experiments (Barnes 1968; Frankova and Barnes 1968; Barnes, Moore, and Pond 1970; Levitsky and Barnes 1973), prefer to speak of the interaction between malnutrition and environmental stimulation. The similarity of the biochemical changes produced in the brain by nutrition or by stimulation, have led them to consider that the physiological mechanisms which may be responsible for the long term effects of early stimulation may not be operative if a concurrent state of malnutrition is present during a critical period of development. Malnutrition may thus change the experience of perception of the environment by physiologically rendering the animal less capable of receiving or integrating, or both, information about the environment. These authors have also considered that even in the absence of biochemical alterations of the brain, malnutrition may elicit behavior that is incompatible with the incorporation of environmental information necessary for optimum cognitive development. Behavior primarily food-oriented and behavior expressed as apathy and social withdrawal are two examples of the kind of behaviors exhibited with a very high frequency by malnourished subjects.

At present we are just beginning to have enough data to tease out the specific contributions of a lack of nutrients inadequate stimulation and diminished experiential opportunities to defective cognitive function. It is most probable that all factors are
interdependent and interactive. (Barnes 1976, Cravioto et al. 1966; Pollitt 1973; Richardson 1976). However, the data reviewed leave no doubt that survivors of severe malnutrition show during quite a long time after rehabilitation decreased measured intelligence together with developmental lags in tasks related to the learning of language and of certain basic academic skills. The most important questions to be answered, hopefully by the on going longitudinal growth studies, are related to a documentation of the quantitative effects of deficient nutritional status on mental development, and to the mechanisms of action of malnutrition either alone or in conjunction with the other features of the unfavorable macro- and microenvironments in which malnutrition flourishes.
AKNOWLEDGEMENTS

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Proportions of tall (QU) and short (QL) six year old rural children showing different number of errors in the visual-kinesthetic judgment of nonidentical forms.

Proportions of tall (QU) and short (QL) eight-year old rural children showing different number of errors in the haptic-kinesthetic judgment of nonidentical forms.

Changes in Performance levels on the visual-kinesthetic ability of tall (QU) and short (QL) rural children.

Visual-kinesthetic intersensory development of 78-month-old children with and without antecedents of early severe malnutrition (nonidentical forms).

Visual-kinesthetic Performance (nonidentical forms) obtained by 78-month-old children with and without antecedents of early severe malnutrition matched for total scores on home stimulation.
Table 2

Main style of Response Obtained in Survivors of Early Severe Malnutrition and Controls for Size at Birth, and Sex and I.Q. at 5 years of Age.

("Land of the White Dust")

Proportion of:

<table>
<thead>
<tr>
<th>Behavioral Style</th>
<th>Survivors</th>
<th>Controls Matched for IQ and Sex</th>
<th>Controls for Size at Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>0.57</td>
<td>0.71</td>
<td>0.85</td>
</tr>
<tr>
<td>Not-work</td>
<td>0.43</td>
<td>0.29</td>
<td>0.15</td>
</tr>
<tr>
<td>Work Verbal</td>
<td>0.62</td>
<td>0.80</td>
<td>0.75</td>
</tr>
<tr>
<td>Work Nonverbal</td>
<td>0.38</td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>Not-Work verbal</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Competence</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Not-Work Nonverbal</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Passivity</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
ERRORS OF EQUIVALENCE
HAPTIC-KINESTHETIC

8 YEARS
QL -----
QU -----
ERRORS OF EQUIVALENCE
VISUAL - KINESTHETIC

NUMBER OF ERRORS

CUMULATIVE PERCENTAGE OF CHILDREN

6 YEARS
QL: ---
QU: ---

8 YEARS
QL: ----
QU: ----
ERRORS OF EQUIVALENCE
VISUAL-HAPTIC

6 YEARS
OL ---
QU ---

CUMULATIVE PERCENTAGE OF CHILDREN

NUMBER OF ERRORS

0 1 2 3 4 5 6 7 8
VISUAL-KINESTHETIC INTERSENSORY DEVELOPMENT OF
78-MONTH-OLD CHILDREN WITH AND WITHOUT
ANTECEDENTS OF EARLY SEVERE MALNUTRITION
(NON-IDENTICAL FORMS)
"LAND OF THE WHITE DUST"

![Graph showing cumulative proportion of children versus number of errors with and without antecedents of early severe malnutrition.](image-url)
VISUAL-KINESTHETIC PERFORMANCE (NON-IDENTICAL FORMS) OBTAINED BY 78-MONTH-OLD CHILDREN WITH AND WITHOUT ANTECEDENTS OF EARLY SEVERE MALNUTRITION MATCHED FOR TOTAL SCORES ON HOME STIMULATION

"LAND OF THE WHITE DUST"

![Graph showing cumulative proportion of children with and without antecedents of early severe malnutrition.](image)
<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>COUNTRY</th>
<th>CHILDREN'S AGE WHEN MALNOURISHED</th>
<th>CHILDREN'S AGE WHEN TESTED</th>
<th>TESTS ADMINISTERED</th>
<th>COMPARISON GROUP</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauk and Najdavi</td>
<td>Yugoslavia</td>
<td>4-14 Months</td>
<td>7-14 Years</td>
<td>Stanojevic's Adaptation of Binet-Simon</td>
<td>Children of unskilled Workers</td>
<td>Intensity and Duration of Malnutrition in Early Life appeared to be related to magnitude of intellectual deficit after rehabilitation</td>
</tr>
<tr>
<td>Liang, et al. (1967)</td>
<td>Indonesia</td>
<td>2-4 Years</td>
<td>5-12 Years</td>
<td>Goodenough Wechsler</td>
<td>Age-Nates Whose nutritional status at age 2-4 years was known</td>
<td>Previously Malnourished children had significantly lower scores than the children who were regarded as non-malnourished during the 2-4 year age period.</td>
</tr>
<tr>
<td>Chempokam, Srikantia</td>
<td>India</td>
<td>10-36 Months</td>
<td>8-11 Years</td>
<td>Specially designed tests, standardized in a comparable population</td>
<td>Children Matched for age, sex, religion, caste, socioeconomic status, family size, birth order, parent's education, locality and school</td>
<td>Lower intellectual performance of previously malnourished children. Differences were marked in the younger age group.</td>
</tr>
<tr>
<td>Guthrie, et al.</td>
<td>Philippines</td>
<td>Presumably at Preschool Age</td>
<td>School Age</td>
<td>Philippine Non-Verbal Intelligence Test</td>
<td>Height gradient within the sample studied</td>
<td>Taller children at all ages performed better on intelligence than shorter children.</td>
</tr>
<tr>
<td>Guillen-Alvarez</td>
<td>El Salvador, CA</td>
<td>3-9 Months</td>
<td>10-12 Years</td>
<td>Raven, Koch, Goodenough</td>
<td>Rural children same age and socioeconomic status</td>
<td>Survivors of Malnutrition clustered on the lowest region of the I.Q. score distribution.</td>
</tr>
<tr>
<td>Hoornweg and Stanfield</td>
<td>Uganda</td>
<td>Below 27 Months</td>
<td>11-17 Years</td>
<td>Raven, Wechsler, WAIS, Porteus, Murray, Knox, Lincoln-Careky</td>
<td>Children with records of good nutrition and growth during first 2-years of life</td>
<td>Except for verbal abilities, a maze test and a short memory test, survivors of malnutrition had lower performance levels in all the other tests. In general those who suffered malnutrition at a younger age did poorer, particularly in several aspects of memory and learning.</td>
</tr>
</tbody>
</table>