Effects of missing breakfast on the cognitive functions of school children of differing nutritional status

Donald T Simeon and Sally Grantham-McGregor

ABSTRACT We examined the effects of omitting breakfast on the cognitive functions of three groups of children: stunted, nonstunted controls, and previously severely malnourished. They were admitted to a metabolic ward twice. After an overnight fast half the children received breakfast on their first visit and a cup of tea the second time. The treatment order was reversed for the other half. When breakfast was omitted, both the stunted and previously malnourished groups responded similarly. The malnourished groups had lower scores in fluency and coding whereas the control group had higher scores in arithmetic. The children were divided into wasted and nonwasted groups. Wasted children were adversely affected in the digit span backwards tests, and wasted members of the malnourished groups were adversely affected in efficiency of problem solving and those in the control group in digit span forwards. These results indicate that cognitive functions are more vulnerable to missing breakfast in poorly nourished children.

KEY WORDS Breakfast, fasting, severe malnutrition, stunting, wasting, cognitive functions

Introduction

Although school feeding programs have been in existence for many years, evaluations have been few and have generally lacked scientific rigor (1-3). The main outcome variables have been nutritional status (4-9), school attendance (5, 9, 10), school achievement (4, 5, 10, 11), and classroom behavior (12-14). Benefits have been found in all these variables; however, findings have been inconsistent except in the case of behavior. Some of the inconsistencies may be explained by differences in the initial nutritional and socioeconomic status of the samples.

In a study in Jamaica (10), when breakfast was given to a group of poor and mostly undernourished children for one semester, there was an improvement in school achievement but no impact on weight or height. The mechanism of the improvement was not clear but in general where benefits have been found in school achievement or behavior it has been suggested that the alleviation of hunger may play an important part (1, 2, 10, 13).

There have been several studies of the effects of short-term fasting in school children (15-17). English studies of secondary school students (15) found that omitting breakfast had no effect on their performance at arithmetic, short-term memory, and attention-demanding tasks. A study of North American children aged 9-11 y (16) found that omitting breakfast had a beneficial effect on short-term memory. However it had an adverse effect on the problem solving ability of children with low IQs but not in those with high IQs. When the American study was replicated (17), it was found that short-term fasting had an adverse effect on problem solving in all the subjects regardless of their IQs. There was also an increase in attention to task-irrelevant information. The beneficial effect on short-term memory was not replicated. Therefore, the findings of these studies have been inconsistent, with either few or no detrimental effects being demonstrated.

The subjects in each of the studies of the effects of missing breakfast were adequately nourished. There is a danger that these findings may influence policy decisions on school feeding, not only in developed countries but also in developing ones. Undernutrition is endemic in these countries and children who are undernourished are more likely to be exposed to hunger. Furthermore they may react differently.

An extreme example of undernutrition is early-childhood severe malnutrition. Survivors generally have lower IQs (18-20) and school achievement levels (21, 22)
BREACKFAST AND CHILDREN'S MENTAL FUNCTION

and more behavioral problems (21, 23) than matched comparison children several years later. It is possible that these children may be particularly vulnerable to fasting.

We have, therefore, investigated the effect of missing breakfast on the cognitive function of the following groups: linear-growth-retarded school children (stunted), matched control children who were not growth-retarded, and children who were severely malnourished in early childhood.

It is generally considered that low weight-for-height (wasting) indicates recent nutritional experiences whereas stunting, or low height-for-age, is the best indicator of the duration of undernutrition (24). In addition, low height-for-age is the commonest form of undernutrition in developing countries (25). The undernourished group in this study was therefore selected by degree of stunting. The effect of degree of wasting was also examined.

Methods

Sample

The study comprised three groups of children aged 9–10.5 y, each with 30 subjects. The children had no obvious mental or physical handicap. Only one child was selected per household. Group 1 was the previously severely malnourished group—subjects who were identified from hospital records and had been admitted to the University Hospital of the West Indies (UHWI) for severe malnutrition during the first 2 y of life; group 2 was the stunted group—children whose heights were below -2 SDS of the NCHS standards (26); and group 3 was the control group—children whose heights were above -1 SD of the NCHS standards. Groups 2 and 3 were identified from three primary schools located in poor areas close to the UHWI. The stunted children were identified first and then the control children were selected from the same class. They were matched for gender and area of residence. Where more than one child was available, the nearest in age was used. There were 19 boys and 11 girls in group 1 and 15 boys and 15 girls in each of groups 2 and 3.

Tests of cognitive functions

The battery of tests included both measures of fine-grained levels of cognitive functions and more global or classroom-type tasks (Table 1). They included three subtests of the Wechsler Intelligence Scale for Children (27): arithmetic, digit span, and coding. The arithmetic test comprised mental arithmetic problems, each having a time limit. The score represents the total number of correct answers.

The digit-span test involved the immediate recall of increasingly longer strings of digits that were read to the children. One set had to be recalled forward as they were given and a second set had to be recalled backwards. The forward and backward items were analyzed separately and the children's scores represent the total number of correct responses.

In the coding test the children had to substitute symbols for numbers as quickly as possible. The score represents the total number of correct symbols written during a fixed time.

These three tests were chosen because performance on them is affected by attention and distractibility (28), which we thought were likely to be susceptible to the omission of breakfast. In addition, the arithmetic test measures computational skills and the coding test measures visual short-term memory and clerical speed and accuracy. The forward items of the digit span test measure auditory short-term memory whereas the backward set includes an immediate processing element.

Two subtests of the Clinical Evaluation of Language Functions (29) were also used: fluency and listening comprehension. The fluency test required the children to name as many items as possible in two different categories. The score represents the number of items named in a limited time period. This test was used to measure generation of ideas and motivation. In the listening comprehension test four short stories were read to the children who then had to answer questions about them and this test measures attention, auditory short-term memory, and comprehension and resembles work performed in school.

The other two tests used, the Matching Familiar Figures Test (MFFT) (30) and the Hagen's Central- incidental task (HCI) (31), were previously shown to be sensitive to the omission of breakfast (16, 17). For each item of MFFT, the children were presented with two cards. On one card was the picture of an object and on the other were a number of variant pictures of the same object. The children had to choose which of the pictures on the second card was exactly like that on the first. The scores included the number of errors made before the correct picture was identified and the latency time, which was the time taken before the children's first response.

The number of errors made is a measure of problem-solving ability whereas the latency time measures reaction time. The MFFT comprised an easy and a hard set, which were analyzed separately.

The MFFT was analyzed in terms of impulsivity and efficiency of problem solving. Firstly, Z scores were computed from the children's number of errors and mean latency time. Efficiency scores were computed by adding the Z score of total errors to the Z score of mean latency time; impulsivity scores were computed by subtracting the Z score of the mean latency time from the Z score of the total errors (32), ie,

\[ \text{Efficiency} = Z\text{ score (errors)} + Z\text{ score (latency)} \]
The presence of certain household possessions, including television, radio, stove, and refrigerator, was also counted. The rating ranged from 3.0 (worst housing) to 9.0 (best housing). The central task measures visual short-term memory whereas the incidental task is a measure of attention to task-irrelevant information. By its nature the incidental task was only valid for the first test session and therefore it was not repeated on the second visit.

Before the study all tests except the HCI incidental task were repeated in 10 children within 1 wk. The test-retest correlations were significant and ranged from 0.66 to 0.97. The Spearman-Brown split-half reliability (33) for the HCI incidental task was 0.62 (Table 1).

### Procedure

After the subjects were identified, their homes were visited and consent to participate in the study was obtained from their parents. Details of their social background were obtained and their housing was scored on a scale that gave equal weighting to quality of water supply, sanitation, and crowding (34). The rating ranged from 3.0 (worst housing) to 9.0 (best housing). The presence of certain household possessions, including television, radio, stove, and refrigerator, was also counted.

The subjects were then admitted overnight, two at a time, to a special research ward on two occasions 1 wk apart. They entered in the afternoon and at 1700 they received a standard dinner of chicken, bread, and french fried potatoes that provided ~940 kcal. On the afternoon of their first visit they were given the Peabody Picture Vocabulary Test (PPVT) to measure their IQs (35).

At 0800 the next day they were given either a standard breakfast (Table 2) providing 590 kcal (~25% of their daily caloric requirement) or a cup (~185 mL) of tea sweetened with aspartame. The breakfast comprised items from the Jamaican government school feeding program. It is common for many poor Jamaican children to have only a cup of tea before going to school. Therefore it was hoped that by providing tea the children would not have been alerted to the fact that something unusual was happening. However the design was not truly double-blind. The level of aspartame used (< 4 mg/kg) was not expected to affect their mental functions (36).

By systematic random assignment, half the children received breakfast on the morning of their first visit and the tea on the morning of their second visit. The treatment order was reversed for the other half of the children. At 1100 the tests of cognitive functions were given by a tester who was unaware of the children's group or fasting state. Each test session lasted for ~45 min.

After the tests the children were given lunch and then taken home. The subjects weights and heights were measured following established procedures (37) on the morning of their first visit.

Permission to conduct this study was obtained from the Ethics Committee of the UHWI.

### Statistical analysis

The weights and heights were expressed as a percentage of the expected value (NCHS standards) for the children's age and sex. Group differences in mean age, anthropometric variables, IQ scores, and social-background variables were examined by analyses of variance (ANOVAS) or chi-square tests where appropriate (38).

The experimental findings for the tests of cognitive functions, with the exception of the HCI incidental task, were examined by factorial repeated-measures analyses of variance and covariance. The previously severely malnourished and the stunted groups behaved similarly when they missed breakfast, and there was no significant difference between these two groups for any of the cognitive tests. They were therefore combined and compared with the control group to test for treatment-by-group effects.

The scores on the children's first and second visits were the dependent variables in the repeated-measures analyses. Therefore the test-retest effect was the within-subject factor. Treatment and nutritional group were used as between-subjects factors. To examine the effects of wasting, the sample was divided into a wasted and nonwasted set, defined for this study as children with weight-for-height below and above 90% of the expected value, respectively (24). There were 30 wasted children who were evenly distributed among the original three groups. The ANOVAs with repeated measures were then rerun with wasting as an added between-subjects factor.

IQ was used as a covariate because there was a group difference but it did not significantly change the main findings. Weight-for-height was also used as a covariate when treatment and group were used as factors and it too did not change the main findings. Consequently, only the results of the ANOVAs with repeated measures will be reported.

The HCI incidental task was not repeated on the children's second visit. Therefore the scores of the children who had breakfast on the first visit were compared with those who did not by ANOVA. Factors included whether they had fasted or not, nutritional group, and wasting. When IQ was used as a covariate it was not significant.

### Results

The characteristics of the children and their social backgrounds are shown in Table 3. There were no difference between groups in the mean age and weight-for-height of the children. However, the control children had higher IQ scores than did the other two groups (AN-
TABLE 3
Age, IQ scores, anthropometric indices, and demographic characteristics of the sample by group

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Previously malnourished (n = 30)</th>
<th>Stunted (n = 30)</th>
<th>Control (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mo)</td>
<td>117.2 ± 6.4*</td>
<td>116.8 ± 6.7</td>
<td>115.1 ± 5.5</td>
</tr>
<tr>
<td>IQ score†</td>
<td>62.3 ± 16.8</td>
<td>62.8 ± 11.3</td>
<td>72.4 ± 11.8</td>
</tr>
<tr>
<td>Height-for-age (%‡)</td>
<td>95.6 ± 4.5</td>
<td>89.3 ± 1.4</td>
<td>99.7 ± 2.4</td>
</tr>
<tr>
<td>Weight-for-age (%)‡</td>
<td>92.3 ± 6.6</td>
<td>93.2 ± 5.4</td>
<td>93.6 ± 7.6</td>
</tr>
<tr>
<td>Weight-for-age (%)‡</td>
<td>81.6 ± 11.5</td>
<td>68.6 ± 5.6</td>
<td>92.2 ± 10.1</td>
</tr>
<tr>
<td>Socioeconomic characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing rating</td>
<td>5.8 ± 1.6</td>
<td>5.6 ± 2.1</td>
<td>6.1 ± 2.2</td>
</tr>
<tr>
<td>Household possessions</td>
<td>1.8 ± 1.3</td>
<td>2.0 ± 1.6</td>
<td>2.6 ± 1.4</td>
</tr>
<tr>
<td>Female caretaker education (§)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>12</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Grades 1–4</td>
<td>32</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Grades 5–9</td>
<td>44</td>
<td>63</td>
<td>70</td>
</tr>
<tr>
<td>Secondary school</td>
<td>12</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

* ± SD.
† ANOVA, p < 0.01.
‡ ANOVA, p < 0.001.
§ One child in the previously malnourished group had no female caretaker and n = 29.

OVA, F = 5.3, p < 0.01; post-ANOVA comparisons: control vs stunted, p < 0.01, and control vs previously malnourished, p < 0.01. There were group differences as expected in height-for-age (ANOVA, F = 89.6, p < 0.001) and weight-for-age (ANOVA, F = 46.7, p < 0.001). The mean height-for-age and weight-for-age of the previously malnourished group were greater than those of the stunted group (post-ANOVA comparisons, p < 0.001 for both). However they were less than those of the control group (post-ANOVA comparisons, p < 0.001 for both).

All groups had poor housing and few household possessions. There was no difference between the groups. The female caretakers in the different groups had similar educational levels and few had attended secondary schools.

The scores of the cognitive tests with and without breakfast are shown in Table 4 and the statistical findings of the ANOVAs with repeated measures with group, treatment, and wasting as factors are given in Table 5.

**Fluency (Fig 1)**

In the fluency test the groups behaved differently on missing breakfast. There was no change in score in the control group whereas the score of the combined malnourished group deteriorated in the fasted state, producing a significant treatment-by-group effect (post-ANOVA comparisons of fed vs fasted states, combined malnourished groups, p < 0.001). When wasting was used as a factor, there was no new significant finding.

**Arithmetic (Fig 1)**

The control children had a higher score in the arithmetic test when they had no breakfast whereas the combined malnourished group was not affected. This produced a significant treatment-by-group effect (post-ANOVA comparisons of fed vs fasted states, control group, p < 0.001). When wasting was used as a factor, there was no new significant finding.

**Coding (Fig 1)**

There was no significant group, wasting, treatment-by-group, treatment-by-wasting, or treatment-by-group-by-wasting effect for the coding test. However, the treatment effect approached significance (p < 0.08). When the scores of the groups were analyzed separately, the control group was not affected whereas the combined malnourished group had lower scores in the fasted state (ANOVA with repeated measures for combined malnourished group, treatment, p < 0.05).

**Digit-span-backward items (Fig 2)**

When treatment, group, and wasting were used as factors, the wasted children of the total sample had lower scores in the fasted state whereas the nonwasted children were not affected. This produced a significant treatment-by-wasting effect (post-ANOVA comparison of fed vs fasted states, wasted children of the total sample, p < 0.05).

**Digit-span-forward items (Fig 3)**

When treatment, group, and wasting were used as factors, there was a significant treatment-by-group-by-wasting effect for the digit-span-forward test. The wasted children of the control group had lower scores in the fasted state whereas the nonwasted members of this group had higher scores.

Neither the wasted nor the nonwasted members of the combined malnourished group were affected when they went without breakfast (post-ANOVA comparisons of fed vs fasted states: wasted children of control group, p < 0.02, and nonwasted members of the control group, p < 0.05).

**MFFT—easy items (Fig 3)**

When the efficiency scores of the easy items of the MFFT were examined with treatment, group, and wasting as factors, there was a significant treatment-by-group effect. The controls improved on missing breakfast (ie, they responded faster and made fewer errors) whereas the combined malnourished group was not affected. There was also a treatment-by-wasting effect with the nonwasted children not being affected whereas the wasted children deteriorated on missing breakfast. However, the latter effect was due solely to the wasted mem-
Results of ANOVA of test scores on children's first admission.

### TABLE 4

Scores of the tests of cognitive functions with and without breakfast by group*

<table>
<thead>
<tr>
<th></th>
<th>Previously malnourished</th>
<th>Stunted</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Breakfast</td>
<td>No breakfast</td>
<td>Breakfast</td>
</tr>
<tr>
<td>Fluency</td>
<td>23.9 ± 6.8</td>
<td>21.8 ± 7.1</td>
<td>22.2 ± 6.1</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>7.5 ± 2.9</td>
<td>7.5 ± 3.1</td>
<td>7.5 ± 1.9</td>
</tr>
<tr>
<td>Coding</td>
<td>21.7 ± 13.3</td>
<td>20.6 ± 12.9</td>
<td>22.9 ± 12.3</td>
</tr>
<tr>
<td>Digit span</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward items</td>
<td>5.3 ± 1.9</td>
<td>5.2 ± 2.0</td>
<td>5.3 ± 1.7</td>
</tr>
<tr>
<td>Backward items</td>
<td>2.8 ± 2.4</td>
<td>2.7 ± 2.2</td>
<td>2.6 ± 1.6</td>
</tr>
<tr>
<td>HCI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>6.0 ± 1.9</td>
<td>5.7 ± 1.4</td>
<td>5.8 ± 1.8</td>
</tr>
<tr>
<td>Incidental</td>
<td>2.5 ± 1.9</td>
<td>2.3 ± 1.3</td>
<td>1.5 ± 1.5</td>
</tr>
<tr>
<td>Listening comprehension</td>
<td>10.5 ± 5.1</td>
<td>10.2 ± 5.2</td>
<td>10.0 ± 4.0</td>
</tr>
<tr>
<td>MFFT easy items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>7.9 ± 4.3</td>
<td>8.0 ± 4.9</td>
<td>8.5 ± 4.5</td>
</tr>
<tr>
<td>Latency</td>
<td>8.4 ± 5.6</td>
<td>8.2 ± 5.4</td>
<td>8.1 ± 5.9</td>
</tr>
<tr>
<td>Efficiency</td>
<td>−0.14 ± 0.85</td>
<td>−0.01 ± 0.84</td>
<td>−0.08 ± 0.97</td>
</tr>
<tr>
<td>Impulsivity</td>
<td>−0.07 ± 1.55</td>
<td>−0.03 ± 1.75</td>
<td>0.11 ± 1.54</td>
</tr>
<tr>
<td>MFFT hard items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>16.4 ± 5.9</td>
<td>15.8 ± 6.1</td>
<td>17.9 ± 5.8</td>
</tr>
<tr>
<td>Latency</td>
<td>9.7 ± 8.0</td>
<td>11.4 ± 13.0</td>
<td>9.6 ± 10.0</td>
</tr>
<tr>
<td>Efficiency</td>
<td>−0.11 ± 1.22</td>
<td>−0.03 ± 1.08</td>
<td>0.14 ± 1.42</td>
</tr>
<tr>
<td>Impulsivity</td>
<td>−0.10 ± 1.40</td>
<td>−0.11 ± 1.67</td>
<td>0.17 ± 1.47</td>
</tr>
</tbody>
</table>

* x ± SD.

...numbers of the combined malnourished group were less efficient whereas the nonwasted members of this group were not affected when they had no breakfast (post-ANOVA comparisons of fed vs fasted states: controls, p < 0.05; wasted children of the total sample, p < 0.01; and

### TABLE 5

Results of the multifactor ANOVA with repeated measures for the tests of cognitive functions

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Group</th>
<th>Wasting</th>
<th>Treatment by group</th>
<th>Treatment by treatment</th>
<th>Treatment by treatment by wasting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F p</td>
<td>F p</td>
<td>F p</td>
<td>F p</td>
<td>F p</td>
<td>F p</td>
</tr>
<tr>
<td>Fluency</td>
<td>6.8 0.01</td>
<td>0.2 NS</td>
<td>0.0 NS</td>
<td>4.8 0.04</td>
<td>0.2 NS</td>
<td>0.1 NS</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>2.7 0.10</td>
<td>1.8 NS</td>
<td>2.2 NS</td>
<td>4.6 0.04</td>
<td>0.1 NS</td>
<td>2.0 NS</td>
</tr>
<tr>
<td>Coding</td>
<td>3.2 0.08</td>
<td>2.5 NS</td>
<td>0.2 NS</td>
<td>0.6 NS</td>
<td>0.0 NS</td>
<td>0.7 NS</td>
</tr>
<tr>
<td>Digit span</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>0.0 NS</td>
<td>0.1 NS</td>
<td>0.2 NS</td>
<td>0.1 NS</td>
<td>0.6 NS</td>
<td>7.8 0.01</td>
</tr>
<tr>
<td>Backward</td>
<td>0.5 NS</td>
<td>0.1 NS</td>
<td>0.2 NS</td>
<td>0.1 NS</td>
<td>4.6 NS</td>
<td>0.04 0.1</td>
</tr>
<tr>
<td>HCI</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>1.5 NS</td>
<td>0.0 NS</td>
<td>0.0 NS</td>
<td>0.8 NS</td>
<td>0.4 NS</td>
<td>0.9 NS</td>
</tr>
<tr>
<td>Incidental*</td>
<td>0.0 NS</td>
<td>1.2 NS</td>
<td>0.0 NS</td>
<td>1.0 NS</td>
<td>0.2 NS</td>
<td>0.5 NS</td>
</tr>
<tr>
<td>Listening comprehension</td>
<td>0.1 NS</td>
<td>1.5 NS</td>
<td>0.1 NS</td>
<td>0.6 NS</td>
<td>0.3 NS</td>
<td>0.3 NS</td>
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<tr>
<td>MFFT easy items</td>
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<td></td>
<td></td>
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<tr>
<td>Efficiency</td>
<td>2.1 NS</td>
<td>0.04 NS</td>
<td>2.1 NS</td>
<td>4.4 0.04</td>
<td>5.8 0.02</td>
<td>5.7 0.02</td>
</tr>
<tr>
<td>Impulsivity</td>
<td>0.0 NS</td>
<td>0.1 NS</td>
<td>1.3 NS</td>
<td>0.2 NS</td>
<td>0.0 NS</td>
<td>0.0 NS</td>
</tr>
<tr>
<td>MFFT hard items</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.2 NS</td>
<td>0.1 NS</td>
<td>0.3 NS</td>
<td>0.0 NS</td>
<td>0.1 NS</td>
<td>0.2 NS</td>
</tr>
<tr>
<td>Impulsivity</td>
<td>1.8 NS</td>
<td>0.0 NS</td>
<td>0.4 NS</td>
<td>2.2 NS</td>
<td>0.5 NS</td>
<td>0.5 NS</td>
</tr>
</tbody>
</table>

* Results of ANOVA of test scores on children's first admission.
wasted members of the combined malnourished group, \( p < 0.001 \).

**Other tests**

There was no significant effect when breakfast was omitted in the MFFT hard-items test, listening comprehension, and the HCI task.

**Discussion**

The control group was not adversely affected in any of the cognitive tests when breakfast was omitted. They even performed better in arithmetic and were more efficient in problem solving. In contrast, the previously malnourished and the stunted groups were adversely affected in fluency (a measure of generation of ideas and motivation) and coding (visual short-term memory). Relative to the control children they were also adversely affected in arithmetic. The adverse effects of missing breakfast on the previously malnourished and stunted groups remained after controlling for both their level of IQ and degree of wasting. This suggests that the effects were independent of IQ and recent nutritional experience.

Wasted children, regardless of which nutritional group they belonged to, were also adversely affected when they had no breakfast, although this was shown by cognitive tests different from those which showed the stunted and the previously malnourished groups to be affected. Wasted children were adversely affected in the digit-span-backwards test. This is a measure of auditory short-term memory with an immediate processing component.

Consequently, the children affected detrimentally by missing breakfast as shown by most cognitive tests were those who were wasted as well as being either stunted or previously malnourished. These children were also the only ones detrimentally affected in the efficiency of problem solving. The wasted children of the control group were adversely affected in the digit-span-forward test.
is difficult to understand why the wasted children of the malnourished groups were not similarly affected.

The children’s performances on the HCI task and listening comprehension tests were not affected when the children missed breakfast. This may be because of the lack of sensitivity of these tests in the sample of children. Alternatively, it is possible that the omission of breakfast in this sample was not sufficient to affect the functions measured by these tests.

This study did not investigate the mechanisms by which missing breakfast may have affected cognitive functions. However variations in metabolic stress and arousal state are two mechanisms that may be responsible either singularly or in combination and should be explored in follow-up studies. Carbohydrate metabolism and hormone production are adversely affected during severe malnutrition (39) and it is uncertain whether these abnormalities are fully reversed after recovery (40-42). During short-term fasting the hormonal and metabolic changes serve to supply the brain with adequate substrate for its metabolism. Therefore, under short-term fasting conditions malnourished children may be under a greater metabolic stress, which could lead to a deterioration in cognitive performance.

The arousal state of the children may be altered by short-term fasting, which may, in turn, affect their performance. There is evidence that there is a curvilinear relationship between the level of arousal and the quality of performance (43) with optimal performance at moderate levels of arousal and poorer performances at both low and high levels. Clearly, the association is complex and performance depends not only on the level of arousal but also on the type and difficulty of the task and nature of the subjects (44). It is possible that malnourished children may have levels of arousal different from those of the control children.

Because the previous reports of missing breakfast involved only adequately nourished children, comparison of their results with those of this study are limited to the results of our control group. Even this group may not have been adequately nourished because their mean percent expected weight-for-height was only 93.6 (Table 3). One report from England (15) indicated that missing breakfast had no effect on the performance of arithmetic, short-term memory, or attention. In contrast, there was a deterioration in problem-solving ability and improvements in short-term memory and attention to task-irrelevant information in the North American studies (16, 17). We were unable to confirm any of the findings of these latter two studies although they had designs similar to ours. The reasons for the different findings are not clear. Differences in subjects however are associated with differences in arousal levels (44), and the social and economic backgrounds of the control children in the present study would certainly have been more deprived than those of the children in the other reports. This factor could lead to differences in arousal and hence performance.

Because school meals are usually served at lunch time, there is a need to investigate whether the effects of lunch are the same as those of breakfast in undernourished children. In well-nourished adults they are not (45). The timing of school meals may therefore be important. Carrying out the experiment in a hospital ward raises questions of ecological validity (46) and the study needs to be replicated in the school situation.

In conclusion, under controlled conditions previously severely malnourished and stunted children and those who were wasted were adversely affected in a number of cognitive functions when they missed breakfast. This contrasted with children who were neither stunted nor wasted and were not adversely affected. If the effects found here are replicated and found to continue over a period of time, then missing breakfast could be a serious contributor to poor school achievement in undernour-

![DIGIT SPAN - FORWARDS](image)

![MFFT - EFFICIENCY](image)
ished children. Presently the indication is that where resources are limited, school meals should be targeted to undernourished children who are more likely than adequately nourished children to benefit in school-achievement levels.

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References