

Effect of Breakfast Timing on the Cognitive Functions of Elementary School Students

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Objective: To study the effect of breakfast timing on selected cognitive functions of elementary school students.

Design: A 2-week randomized control intervention trial.

Setting: Five elementary schools.

Subjects: The subjects comprised 569 children, 51% of them boys, aged 11 to 13 years; the children were in grades 5 through 6 (17 classes). The subjects lived in different areas and had different socioeconomic backgrounds.

Intervention: Each subject was tested twice, by 2 versions of the Rey Auditory-Verbal Learning Test, 2 alternative forms of the logical memory subtest of the revised Wechsler Memory Scale, and 2 versions of the Benton Visual Retention Test. On the first test, before any nutritional intervention, the subjects were asked to complete a questionnaire about their food intake on the day of testing. Two thirds of the subjects received 200

mL of 3%-fat milk and 30 g of sugared cornflakes for the next 14 days, and all the subjects were reexamined on the 15th day.

Main Outcome Measure: Scoring on the different tests was compared with baseline scores.

Results: After 15 days, children who ate breakfast at school scored notably higher on most of the test modules than did children who ate breakfast at home and children who did not eat breakfast.

Conclusions: Our results indicate that routinely eating breakfast 2 hours prior to being tested does not improve cognitive functions in 11- to 13-year-old elementary school students, but food supplementation 30 minutes prior to taking a test notably improves scoring. We suggest further studies on the relationship between meal content, feeding time, and scholastic performance.

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Editor's Note: This study should generate many hypotheses to explain the results, and I hope they will be tested and published. Sugared cornflakes? . . . Fascinating!

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THE ROLE of breakfast in improving the academic performance of children is still being debated.¹ The School Breakfast Program, created by the US Congress in 1966, has helped children notably improve their academic functioning; however, this improvement has been noted only among low-income elementary school children.² On the other hand, the cognitive functions of poorly nourished children seem to be vulnerable to the effects of a missed breakfast.³ The maximum work rate and out-

put are also notably affected when breakfast is not eaten.⁴ Evidence from the literature indicates that a relatively modest increase in circulating glucose concentrations enhances learning and memory processes in rodents and humans.⁵ Improved performance on a test that included contextual and noncontextual materials has been shown in elderly subjects after increasing blood glucose concentrations.^{6,7} The enhancement of several cognitive functions has been shown in subjects with severe cognitive pathologies, including individuals with the Alzheimer disease and Down syndrome. The effect of glucose on human memory has an inverted-U dose-response curve⁸ and may

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SUBJECTS AND METHODS

SUBJECTS

The subjects comprised 569 children, 51% of them boys, aged 11 to 13 years; the children were in grades 5 through 6 in 5 elementary schools (17 classes). The subjects lived in different areas and had different socioeconomic backgrounds. The study was approved by the Israeli Ministry of Education on the condition that anonymity be respected. Each subject was tested twice, by 2 versions of the Hebrew version of the Rey Auditory-Verbal Learning Test,⁸ in a counterbalance study.

At the first testing session, the subjects were asked to complete a questionnaire in which they were asked whether and what they had eaten that morning. If the subjects had eaten, they were asked to specify items and quantities on a list that included most of the possibilities of Israeli breakfast foods. The children were tested in the second hour of school (between 8:55 and 9:35 AM). After the first test, two thirds of the subjects were enrolled in a program that lasted 14 days, in which each subject received 30 g of sugared cornflakes and 200 mL of 3%-fat cow's milk each morning between 8:00 and 8:20 AM. The subjects were asked not to eat breakfast at home during this period. Approximately one third of the subjects were used as controls and received no instructions regarding breakfast habits.

At the end of the 14 days, each subject was asked to participate in the alternative version of the Rey test. The controls were asked if they had eaten breakfast that morning. During the study, neither the subjects nor the controls were aware of the length of the study period or of the second test.

COGNITIVE TESTS

The Rey Auditory-Verbal Learning Test was used to measure cognitive functions. The test measures several variables of learning and memory simultaneously. A list of 15 common nouns is read to the subjects in 5 consecutive trials; each reading is followed by a free recall. In trial 6, an interference list of 15 new common nouns is presented, followed by a free recall of these nouns. In trial 7, without an

additional reading, the subjects are asked to recall the first list. Twenty minutes later, and again without an additional reading, the subjects are asked once more to recall the first list (trial 8). Next, in trial 9, they are given a list of 50 words (15 from the first list, 15 from the second, and 20 new common nouns) and asked to identify the 15 words from the first list. In trial 10, following the recognition task, the subjects are presented with the first list in a different order to that used originally and are asked to rewrite the words in their original order. The total testing time was 50 minutes. The Rey Auditory-Verbal Learning Test measures different learning and memory skills, including the following: immediate recall (trial 1 score), best learning (trial 5 score), and mean learning (average score on trials 1-5). These scores measure the capacity to recall and accumulate words across learning trials. The ability to cope with interferences is tested in trials 6 and 7 (proactive, trial 6; retroactive, trial 7). Delayed recall, recognition, and memory of temporal order are tested in trials 8 through 10, respectively.⁸

In addition to the Rey test, memory for narrative prose was tested by 2 alternative forms of the logical memory subtest of the revised Wechsler Memory Scale, and visual memory was tested by 2 versions of the Benton Visual Retention Test. Both tests were performed during the 20-minute break from the Rey test.

STATISTICS

Groups of subjects (ie, those who ate breakfast and those who did not eat breakfast before test 1 and those who ate breakfast at home, those who ate breakfast at school, and those who did not eat breakfast before test 2) were compared in an analysis of variance that included the test version and gender as additional factors. Group means were adjusted for the nonproportional allocations on these 2 factors.

Factor analysis was used to reduce the dimensionality of the cognitive function measurement, based on the correlations between the scores of the different trials.⁹ The factors were then subjected to variance maximization (VARIMAX) rotation to emphasize the trials with the greatest contribution to each factor. As the story and picture tests were not part of the Rey battery of tests, they were excluded from the factor analysis.

be related to the attenuation of opiate inhibition caused by acetylcholine release in the hippocampus.⁵

We investigate the possibility that children who eat breakfast perform better on short-term cognitive functions.

RESULTS

The study population comprised 491 subjects for test 1, and 503 subjects for test 2; 430 subjects participated in both tests.

Of the subjects participating in test 1, 77% ate breakfast on the morning of the test. The breakfast habits of boys and girls were found to be similar.

The test scores on the first round of those who ate breakfast were compared with those who did not eat

breakfast on the day of the test in a model that included test version and gender. The possibility of interactions was tested and found to be insignificant in every case. On immediate recall, children who ate breakfast on the test day scored significantly higher than those who did not eat breakfast (mean \pm SE, 7.00 ± 0.12 vs 6.49 ± 0.22 , $P = .04$). No other differences were found between the 2 groups on the raw trial scores. The results of the first test were subjected to principal components factor analysis. Three factors were selected using the criterion that the eigenvalue of a factor should be at least 1. The factor axes were redefined after VARIMAX rotation. The coefficients for factor calculation are given in **Table 1**. The 3 factors, acquisition, delayed recognition, and delayed recall, were based on the variables that gave the major contribution to the value of each factor. Groups of children

were compared in the same way as described earlier for each of the 3 factor scores. No notable differences were found between the 2 groups (**Figure 1**).

Test 2 comprised 322 subjects who ate breakfast at school and 181 control subjects. Of the control subjects, 66% ate at home on the morning of the test. Significant statistical differences were found on most of the scores between subjects who ate breakfast at school and those who ate breakfast at home or those who did not

eat breakfast (**Table 2**). Three factor scores were calculated for each of the participants in the second test using the scoring coefficients given in Table 1. This summation of the data emphasized the advantages of those who ate breakfast at school compared with the other 2 groups (**Figure 2**).

COMMENT

Our study indicates that, on most of the tests studied, 11- to 13-year-old elementary school children who routinely eat the usual Israeli breakfast do not perform better than those who start the day without breakfast when studied 1½ to 2 hours later.

However, significant statistical differences in almost all scores were found between those who had become accustomed to eating at school and those who ate earlier at home or those who ate nothing. (As most children live within a short walking distance of their school, additional snacking before testing was unlikely). These differences may indicate the importance of timing or the possible importance of breakfast content in these processes. These results coincide with recent studies in animals and humans that show that an increase in glucose concentrations prior to or immediately after a learning session improves cognitive functions and memory skills.⁶

Different studies have indicated a reversed-U-shaped glucose curve for the process of improving memory skills,¹⁰ and this may explain some of the different scoring in test 2. In our study, the effect of an increased glucose concentration may be indistinguishable when testing is performed 2 hours after the meal; however, performance improved notably when subjects ate a meal shortly before being tested.

The control of blood glucose and insulin levels depends on the starch and nonstarch polysaccharide contents of the meal.¹¹ This phenomenon has been expressed in the glycemic index of foods.¹² The routine breakfast, as reported by the students, was a cup of chocolate milk with a few biscuits or a cup of milk with a handful of cornflakes; only 10% of the children ate bread, salad, or other food items with a higher glycemic index. Therefore, the hypothesis that most of the children no longer

Table 1. Standardized Scoring Coefficients for Calculation of Factors

Variable	Acquisition	Delayed Recognition	Delayed Recall
Proactive interference	0.45	-0.19	-0.09
Immediate recall	0.41	-0.12	-0.17
Retroactive interference	0.32	0.04	0.07
Best learning	0.23	0.19	0.23
Recognition	-0.17	0.65	-0.07
Temporal order	-0.04	0.54	0.02
Delayed recall	-0.07	-0.06	0.93
Percentage of variance explained	20.1	13.7	10.6

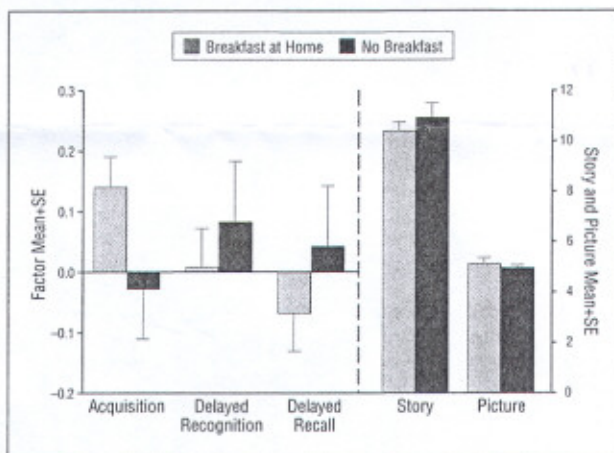


Figure 1. Test 1. Factor scores of children who ate breakfast at home and children who did not eat breakfast on the day of testing.

Table 2. Scores for the Different Trials on Test 2*

Variable	Children Who Did Not Eat Breakfast	Children Who Ate Breakfast at Home	Children Who Ate Breakfast at School	Analysis of Variance F
Immediate learning	6.52 ^{ab} +0.28	6.36 ^b +0.20	6.82 ^a +0.13	1.98
Best learning	11.28 ^b +0.31	11.56 ^b +0.22	12.16 ^a +0.14	4.99 [‡]
Mean learning	9.49 ^b +0.24	9.55 ^b +0.78	10.10 ^a +0.11	5.34 [‡]
Proactive interference	5.95 ^b +0.26	5.62 ^b +0.19	5.92 ^a +0.12	0.99
Retroactive interference	6.39 ^b +0.50	6.28 ^b +0.36	10.25 ^a +0.23	56.31 [§]
Delayed recall	7.91 ^{ab} +0.57	7.31 ^b +0.41	8.50 ^a +0.26	3.06 [†]
Recognition	13.29 ^b +0.23	13.61 ^b +0.17	14.71 ^a +0.11	8.14 [§]
Temporal order	0.54 ^{ab} +0.04	0.48 ^b +0.03	0.61 ^a +0.02	7.73 [§]
Story	7.46 ^b +0.80	8.31 ^b +0.52	10.24 ^a +0.38	7.07 [§]
Picture	4.70 ^b +0.25	4.93 ^b +0.18	5.50 ^a +0.11	6.45 [‡]

* Values are expressed as means plus 1 SE. Means bearing the same letter do not differ significantly at P=.05.

†P<.05.

‡P<.01.

§P<.001.

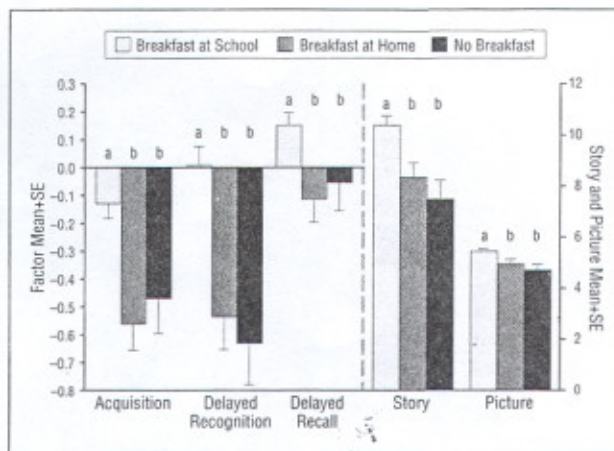


Figure 2. Test 2. Factor scores of children who ate breakfast at school, children who ate breakfast at home, and children who did not eat breakfast on the day of testing. See the first footnote in Table 2 regarding "a" and "b."

had elevated blood glucose levels by the second hour of school was supported. However, the better scoring on test 2 by subjects who were fed in school may, theoretically, have been affected by the interruption of the usual school routine. The study was especially designed to prevent the effect of this phenomenon by continuing the feeding for a period of 2 weeks and by inserting a study period between the breakfast and the test. Our results coincide with the results of a study conducted by Matheson,¹⁽⁴⁷⁸⁾ who assessed the value of a midmorning orange juice feeding during a 10-day period testing arithmetic and letter symbol decoding. Orange juice supplementation was associated with a notable improvement, mainly on tests taken after the feeding at 10:30 AM. Matheson¹⁽⁴⁷⁸⁾ also concluded that students score higher on tasks undertaken shortly after eating food.

We were unable to study the effect of deviation from regular habits (eg, children who normally eat breakfast not eating breakfast or children who normally do not eat breakfast eating breakfast on the day of testing) on the test scoring. Simeon and Grantham-McGregor³ have studied the effect of not eating breakfast in children with different nutritional statuses using the conditions of a metabolic ward; they have found that the cognitive functions of poorly nourished children are more vulnerable to the effects of a missed breakfast. In 2 studies on a few subjects using controlled conditions in a metabolic ward,

Pollitt et al¹³ have shown that skipping breakfast has an adverse effect on the children's late-morning problem-solving performance. Glucose was the only predictor of the behavioral test scores. Both studies showed that children who skipped breakfast remembered irrelevant information better. No information was given regarding previous breakfast eating habits or the exact content of the breakfast given in the ward.

In conclusion, our study indicates a possible role of meals in the learning process. This role can probably be associated with an increase in blood glucose levels and may depend, therefore, on meal content and timing. We suggest further studies on the interrelationships between meal content, feeding time, and scholastic performance.

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