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Effects of Food Snacks on Cognitive Performance in Male College Students

ROBIN B. KANAREK and DAVID SWINNEY
Department of Psychology, Tufts University

The effects of food snacks consumed in the late afternoon on cognitive performance in college-aged men were investigated in two experiments. The effects of the snacks were tested in the same subjects after they either consumed or skipped lunch. In the first experiment, the calorie-rich snack was a confectionery product, while in the second experiment, the snack was fruit-flavored yogurt. In both experiments, performance on cognitive tasks following consumption of the calorie-rich snack was compared to performance following consumption of a very low calorie snack (lemon-lime flavored diet soda without caffeine). Four cognitive tasks were employed: digit span recall (forward and backward), arithmetic reasoning, reading, and attention. In both experiments, subjects recalled significantly more digits in the backward digit span test and responded significantly faster in the attention task when they had consumed the calorific snack than when they had consumed the diet soft drink. Additionally, in Experiment 2, subjects solved significantly more arithmetic problems and solved these problems in significantly less time after eating a fruit-flavored yogurt than after consuming the diet soft drink. Results of these experiments suggest that a late afternoon energy-containing snack can have positive effects on cognitive performance on tasks that require sustained attention.

During the past decade, the idea that nutrition can affect cognitive behavior, that is, the capacity of an individual to think, reason, remember and attend to information effectively, has gained popular acceptance. This acceptance stems, at least in part, from publications in the lay literature asserting the positive, or more frequently negative, effects of certain food components on behavior (e.g. Dufty, 1975; Wurtman, 1986). Unfortunately, these assertions generally are based on anecdotal evidence rather than appropriate scientific research. Only recently have good experimental studies examining the effects of short-term dietary manipulations on behavior been initiated (for review see Spring, 1986).

Initial studies on the significance of short-term nutritional variables on mental capacities focused on the effects of short-term fasting on the cognitive performance of young children (Conners & Blouin, 1982; Pollitt *et al.*, 1978, 1981, 1982). In two experiments, Pollitt and colleagues (1981,1982) reported that skipping breakfast had a deleterious effect on the problem-solving performance of 9-11-year-old well-nourished children. Children who skipped breakfast made more errors on a matching task than children who consumed breakfast, Similar results were obtained by Conners & Blouin (1982) who reported that children who did not eat breakfast made significantly more errors in arithmetic tasks than those who had eaten breakfast.

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Correspondence should be addressed to: Robin B. Kanarek, Department of Psychology, Tufts University, Medford, MA 02155, U.S.A.

David Swinney is now at the City University of New York Graduate Center, 33 W. 42nd Street, New York, NY, U.S.A.

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In contrast to the above, results of recent studies indicate that there is a meal-dependent decrement in cognitive performance following the ingestion of lunch by adult subjects (Craig, 1986; Smith & Miles, 1986 a, b; Smith *et al.,* 1988). Smith & Miles (1986 a) observed that the ability to maintain attention and react quickly to the appearance of a new stimulus was impaired following lunch. Further, Craig (1986) reported that eating lunch led to a decrement in performance on a perceptual discrimination task. While an adverse effect of lunch does occur on some tasks, particularly those requiring focusing and sustaining attention, this effect depends to some degree on the nature of the task, the age, sex, personality and eating habits of the person who consumes the lunch, and the nutritional content of the lunch (Spring *et al.*, 1983, Craig, 1986; Smith & Miles, 1986 a, b).

To extend the examination of the role of short-term nutrient intake in cognitive behavior to another situation, the present experiments investigated the effects of a nutritional supplement, or snack, consumed in the late afternoon on performance of four cognitive tasks. As previous work had demonstrated that lunch can influence performance on cognitive tasks, the effects of the snack were tested in the same subjects when they had consumed a standard lunch and when they had skipped lunch. In the first experiment, the nutritional supplement was a confectionery product, a food item frequently chosen as a late afternoon snack by young adults. In the second experiment, the nutritional supplement was a fruit-flavored yogurt-another frequently consumed snack.

There are numerous cognitive capacities which could have been the target of these studies. At this stage of research in this area, it seemed most appropriate to begin with those capacities that are acknowledged to be fundamental processes underlying cognition-attention and memory. In addition, to provide some information on more integrative cognitive functions, mathematical reasoning and reading skills were assessed.

EXPERIMENT 1

Methods

Subjects

Ten college-aged men (19-22 years of age) were recruited through advertisements in the local college newspaper and selected on the basis of their answers to a nutritional and health questionnaire designed to determine the potential subject's current and past health, and dietary habits. The questionnaire was used to eliminate participation of individuals with any history of diet-related problems (e.g. diabetes, hypoglycemia, food allergies), to ensure that participants were within 90 to 110% of desirable weight as determined from the Metropolitan Life Tables (Metropolitan Life Insurance Company, 1959), to allow for the standardization of intakes from food items (e.g. caffeine, alcohol) which might affect cognitive performance and to equate normal dietary habits (e.g. only subjects who regularly ate breakfast and lunch were chosen for the study).

Materials

The cognitive processes examined in this study fell into four general categories: memory, arithmetic reasoning, reading and attention.

Memory: Memory was examined using forward and backward digit span tests adapted from the WISC test (Prather, 1987). For both the forward and backward digit span tests, materials consisted of two different lists of eight sets of digits. The eight sets of digits in each list were of increasing lengths, beginning with two digits in the first set and extending to nine digits in the eighth set. Each list contained different sets of digits. Each set was recorded on audio tape, with the digits presented 1 sec apart.

Each set of digits was played to the subject, following which the subject was required to repeat the digits on the list in exactly the same order he heard them (forward digit span) or in the reverse order (backward digit span). The longest set length which was recalled correctly for each list (both lists were tested each day of testing) constituted the "score" for that list. The subject's digit span score was the mean of the longest set of digits recalled for the two lists. Separate scores were calculated for the forward and backward digit spans.

Arithmetic reasoning: To test arithmetic reasoning, four different sets of 12 arithmetic word problems, modeled after those in the WISC were used. All sets were pretested by 12 subjects to determine equivalence of difficulty. A different problem set was presented to the subject on each test day.

Each problem in a set was recorded on audio tape and presented, in order of increasing difficulty, over headphones to each subject. The subject was required to calculate the solution to the problem in his head, without aid of paper and pencil, and to speak the answer aloud as soon as he had computed it. A computer-based program initiated a timing sequence at the end of the auditory presentation of each word problem and terminated the timing with the voice-onset of the subject's response. The dependent variables for this task were mean reaction time in seconds to correctly solve arithmetic problems, recorded by the computer, and the mean number of correctly solved problems recorded by the experimenter.

Reading: Reading speed was examined. Four-equivalent sets (each to be presented on a different day of testing) of three 16-line stories were created. These stories were "vague" stories, modeled after those used by Bransford & Johnson (1972), in which heavy use of pronomial anaphora and vague reference were employed. Thus, while each sentence of the story was easily comprehensible, the topic of the story itself was difficult to discern. These vague stories have been shown to cause great difficulty in reading, understanding and memorizing.

The first story in each set was a practice story and was not included in the data anlysis. Each story was presented, line by line, on a CRT display screen. The subject's task was to read each line as quickly as possible (while reading sufficiently well to understand) and to press a button as soon as he was finished. The button press caused the next line of text to appear. A computer recorded the time from the initial presentation of each line of text until the button press for that line.

Attention: Attention was examined through a continuous performance task (CPT). In this task, each subject is presented with 360 items (either a letter or a number) on a computer screen. Each item appeared on the screen for 200 msec followed by an intrastimulus interval of 350msec before the next item appeared. The items were arranged so that for 40 of the 360 items a consonant appeared on a trial followed by a number greater than 25. The subject's task was to detect these situations and press a button whenever they occurred. Reaction time from the onset of the number greater than 25 until the button press was recorded on a Commodore 64 computer. The number of correct detections of the sequence (hits) and the number of false alarm detections (misses) also were calculated. The dependent variables were the mean reaction time to correctly detect targets and the mean number of errors in detection.

Procedure

Each subject came to the laboratory for breakfast (at either 0800 hrs or 0830 hrs), lunch (1200hrs or 1230hrs) and testing (1530hrs or 1600hrs) on the same day of the week for 4 consecutive weeks. Subjects were each tested under four different nutritional conditions. In all conditions, subjects received breakfast in the lab. To help prevent the subjects from gleaning the exact nature of the study, four different breakfasts, equivalent in calories and in the proportion of macronutrients they contained, were used (Table 1). On two of the test days, subjects received lunch and on two days they were not given any lunch when they arrived at the laboratory at 1200 hrs or 1230 hrs. Two different lunches, equivalent in calories and macronutrient content, were employed (Table 1). The lunch/no lunch conditions were factorially crossed with a

TABLE 1
Breakfast and Lunch Menus

	Breakfasts	
Menu 1	1 1/3 cup Wheaties	Calories: 299
	1/2 banana	Protein = 13.0g
	1 cup 2% milk	Carbohydrate = 47.0g
		Fat = 6.5g
Menu 2	1 small pear	Calories: 301
	2/3 cup plain yogurt	Protein = 12.5g
	1/4 cup wheat germ	Carbohydrate= 48.0g
	1 /2 bagel	Fat = 6.5g
Menu 3	1/3 cup orange juice	Calories: 303
	2 slices whole wheat bread	Protein = 12.0g
	2 tsp whipped butter	Carbohydrate = 49.0 g
	1 cup skim milk	Fat = 6.5g
Menu 4	12 grapes	Calories: 303
	1 cinnamon bagel	Protein = 12.0g
	2 tsp whipped butter	Carbohydrate = 49.0g
	1 cup skim milk	Fat = 6.5g
	Lunches	
Menu 1	2 slices whole wheat bread	Calories: 556
	1 small can tuna in water	Protein = 24.0 g
	1/2 cup tomatoes	Carbohydrate = 78.0g
	1/2 cup alfalfa sprouts	Fat = 16.0g
	1 T diet mayonnaise	
	1/2 cup apple juice	
	2 health cookies	
	1 small apple	
Menu 2	1 1/2 cups lettuce	Calories: 559
	1 /2 cup cucumbers	Protein = 29.0 g
	1/2 cup tomatoes	Carbohydrate = 69.0g
	2 oz sliced turkey	Fat= 19.0g
	2 T diet salad dressing	
	1/2 piece pita bread	
	1/2 cup V-8 juice	
	1 small apple	
	1 oz trail mix	

caloric snack/non-caloric snack condition, such that on one day when subjects received lunch, they received a confectionery product and on one day when they received lunch, they were given a non-caloric snack (lemon-lime flavored diet soft drink without caffeine). Similarly, caloric snack/non-caloric snack conditions occurred with the no lunch condition. The caloric content of the 2.16 oz confectionery product was 290 kcal. and the macronutrient content was 9 g protein, 36g carbohydrate and 14g fat. The confectionery product was unwrapped and presented to the subjects on a paper plate. The 12 oz diet soft drink (4 kcal) was poured into an opaque container so that the subjects could not discern its caloric content.

A partial latin square design was employed to assign the order in which subjects received each of the four nutritional conditions and to assign different variants of the cognitive tasks to each subject.

Subjects were asked not to eat any food after 2000 hrs of the evening before they were to be tested and were told not to eat anything after breakfast or after lunch. A questionnaire was administered at the end of testing each day to help determine whether any eating had gone on during these periods (no subjects reported violating the eating prohibitions). The subjects were not informed ahead of time whether they would or would not receive lunch on a given day and were not told the caloric content of the snack. They were told only that the general effects of nutritional variables on cognitive processes were being investigated. Post-test questionnaires revealed that none of the subjects guessed the exact nature of the experiment.

Testing was begun precisely 15 min following eating of the caloric or non-caloric snack. The order of the tests was constant for all subjects: forward and backward digit span (10 min), arithmetic reasoning (10 min), reading (10 min), and CPT (10 min). The experimenters conducting the cognitive tests were blind to the nutritional status of the subjects.

The procedures for this experiment were reviewed and approved by the Tufts University Psychology Department Research Committee. Subjects received payment of $60 after the completion of all four test sessions.

Data Analysis

The results of each of the four cognitive tests were analyzed separately using repeated measure analysis of variance (ALICE Analysis Package). The two independent variables were lunch (lunch/no lunch) and snack (snack/no snack).

Results

Forward Digit Span

No significant differences were observed as a function of nutritional conditions for the forward digit span test (Table 2).

Backward Digit Span

As shown in Table 2, subjects recalled significantly more digits after they had consumed the caloric snack than after they had consumed the noncaloric snack (df =1, 9, $F = 5.3$, $p < 0.05$). No significant effects for lunch or the interaction of the lunch and snack conditions were observed.

Arithmetic Reasoning

The mean number of correctly solved problems was tallied for each subject for each of the four nutritional conditions (Table 3). Subjects did marginally better when they had eaten lunch than when they had not eaten lunch (df = 1, 9, $F = 5.08$, $p < 0.06$).

Additionally, subjects did marginally better when given a confectionery product than when given the low calorie soft drink (df= 1, 9, F=5.10, p<0.06). These data are the result of subjects correctly solving more problems when given lunch and a caloric snack than in any other of the nutritional conditions.

Mean time to correctly solved problems did not differ as a function of either lunch or snack (Table 3).

Reading

No difference in average times to read each line of text were observed as a function of nutritional condition (Table 4).

TABLE 2

Mean number of digits recalled in the forward and backward digit span tests for each of the nutritional conditions

	Lunch	No lunch
Forward Digit-span Test		
Confectionery product	6.8	7.4
Diet soft drink	7.3	7.3
Backward Digit-span Test		
Confectionery product	5.0*	5.1*
Diet soft drink	4.8	4.7

*=number of digits recalled significantly (p<0.05) greater following consumption of the confectionery product than following consumption of the diet soft drink.

TABLE 3

Mean number correct and mean reaction time in seconds to solve arithmatic problems correctly for each of the nutritional conditions

	Lunch	No lunch
Mean Number Correct for Arithmetic Reasoning Problem		
Confectionery product	9.3	8.7
Diet soft drink	8.7	8.7
Mean Reaction Time (sec) to Correctly Solve Arithmel Problems		
Confectionery product	4.13	4.15
Diet soft drink	4.16	4.14

TABLE 4

Mean reading time *per line (sec) of text in each of the nutritional conditions*

	Lunch	No lunch
Confectionery product	2.56	2.57
Diet soft drink	2.56	2.54

TABLE 5

Mean reaction time *(msec) to correctly detect CPT target and mean number of errors in detecting correct sequence of targets under each of the nutritional conditions*

	Lunch	No Lunch
	Mean Reaction Time (msec)	
Confectionery product	417*	410*
Diet soft drink	432	434
	Mean Number of Errors	
Confectionery product	25.1	23.7
Diet soft drink	26.4	26.3

*=mean reaction time significantly ($p<0.05$)less when subjects consumed the confectionery product than when they consumed the diet soft drink.

Attention

The average reaction time to correctly detect targets and the average number of errors in detection were calculated for each subject. Subjects responded significantly faster when they had consumed a caloric snack than when they had consumed the low calorie soft drink (df=1, 9, $F = 6.98$, $p<0.05$) (Table 5). Further, subjects made marginally fewer errors after eating the confectionery product than after drinking the soft drink (df=1, 9, F=4.97, $p<0.06$) (Table 5). No other comparisons were significant.

Practice Effects

While not predicted, examination of the data at the end of the experiment revealed that a practice effect may have occurred on some tasks. Therefore, analyses of variance were performed on the data from each of the above tasks, using weeks as a factor. There were no effects or practice in the forward or backward digit span tests or the CPT task. However, solution time for arithmetic problems showed a significant effect of work of participation (df=3, 27, F=3.4, $p<0.05$), as did reaction time on the reading task (df=3, 27, F=4.1, $p<0.05$). In both cases, these effects were caused by slower times on the first day of participation, independent of the nutritional condition. As a result of this practice effect, in the next experiment, a fifth set of materials was developed to be used for a first "practice" day.

Discussion

The results of this experiment indicate the potentially beneficial effects of a nutritional snack on the performance of cognitive tasks. This effect was observed particularly for tasks which placed demands on attentional components of cognitive processing. Subjects remembered significantly more digits in the backward digit span test when they had consumed a confectionery product than when they had consumed a low calorie soda. This task is generally considered more difficult than the forward digit span task and requires more attention by the subject. A significant effect for the snack also was found in the CPT task. Subjects' response times for correctly identifying a correct target were significantly faster when they had eaten the caloric snack than when they had not. The next study, examined whether similar effects would be observed when subjects were given another commonly consumed food item, fruit-flavored yogurt, as a late afternoon snack.

EXPERIMENT 2

Methods

Subjects

Eight college-aged men, recruited through advertisements in the local college newspaper, were used in this study. The same screening procedures and payment schedule were used as in Experiment 1.

Materials

Materials were the same as those used for Experiment I with the addition of one extra set of each of the tasks for the fifth day of testing. This extra set of materials was equivalent to the other four sets, and was used on the first, practice day of the experiment. The snack in this experiment consisted of an 8 oz fruit-flavored yogurt which contained 240 calories, slightly less calories than the confectionery product used as a snack in Experiment 1. The macronutrient composition of the yogurt was 9 g protein, 43 g carbohydrate and 3 g fat. The non-caloric snack was a 12 oz. lemon-lime flavored diet soft drink without caffeine.

Procedures

The procedures in this study were the same as those in Experiment 1, with the exception of the addition of an extra day of testing. Each subject began the present experiment with a practice session to acquaint them with the tasks. This practice day occurred on the same day of the week as the other four tests. Thus, each subject was required to come to the laboratory on the same day of the week for 5 consecutive weeks.

Results

Forward Digit Span

Subjects recalled marginally more digits when they had consumed a fruit flavored yogurt than when they consumed the diet soda (df=1, 7, F=5.34, p<0.06) (Table 6). No difference in the number of digits recalled was observed as a function of the lunch condition.

Backward Digit Span

Subjects recalled significantly more digits after eating the caloric snack then after eating the non-caloric snack (df=1, 7, F=7.77, p<0.05) (Table 6). No difference in the number of digits recalled was observed as a function of the lunch condition.

Arithmetic Reasoning

Subjects correctly solved significantly more problems after consuming the caloric snack than after consuming the non-caloric placebo (df=1, 7, F=14.6, p<0.01) (Table 7). The lunch condition had no effect on this measure.

Subjects solved the problems significantly more rapidly when they had consumed the fruit-flavored yogurt than when they consumed the diet soda (df=1, 7, F=7.93 p<0.05) (Table 7). There was no effect of lunch on this measure.

TABLE 6

Mean number of digits recalled in the forward and backward digit-span tests for each of the nutritional conditions

	Lunch	No lunch
	Forward Digit-span Test	
Fruit-flavored yogurt	8.1	8.5
Diet soft drink	8.2	7.7
	Backward Digit-span Test	
Fruit-flavored yogurt	6.8*	6.8*
Diet soft drink	5.8	5.2

*=number of digits recalled significantly ($p<0.05$) greater following consumption of the fruit-flavored yogurt than following consumption of the diet soft drink.

TABLE 7

Mean number correct and mean reaction time (sec) to solve arithmetic problems correctly for each of the nutritional conditions

	Lunch	No lunch
Mean number correct for arithmetic reasoning problems		
Fruit-flavored yogurt	8.4*	8.4*
Diet soft drink	7.0	6.7
Mean reaction time (sec) to correctly solve arithmetic problems		
Fruit-flavored yogurt	2.98	3.56
Diet soft drink	4.06	3.65

*=a significantly ($p=0.05$) greater number of problems solved correctly when subjects consumed fruit-flavored yogurt than when they consumed a diet soft drink.

TABLE 8

Mean reading time per line (sec) of text in each of the nutritional conditions

	Lunch	No lunch
Fruit-flavored yogurt	2.17*	2.52
Diet soft drink	2.26*	2.55

*=mean reading time significantly ($p<0.005$) faster when subjects consumed lunch than when they had not consumed lunch.

TABLE 9

Mean reaction time (msec) to correctly detect CPT targets and mean number of errors in detecting correct sequence of targets under each of the nutritional conditions

	Lunch	No Lunch
	Mean Reaction Time (msec)	
Fruit-flavored yogurt	406*	410*
Diet soft drink	441	434
	Mean Number of Errors	
Fruit-flavored yogurt	13	12
Diet soft drink	16	17

*=mean reaction time significantly ($p<0.05$) faster when subjects consumed fruit-flavored yogurt than when they consumed the diet soft drink.

Reading

Subjects read each line of the stories significantly faster when they had consumed lunch than when they had not consumed lunch ($df=1, 7$, $F=17.40$, $p<0.01$) (Table 8). Additionally, subjects read significantly more rapidly after eating the caloric snack than after the low calorie snack ($df=1, 7$, $F=8.34$, $p<0.05$).

Attention

Subjects correctly detected targets significantly more rapidly after eating the nutritional snack than after the diet soft drink ($df=1, 7$, $F=10.21$, $p<0.05$) (Table 9). Additionally, subjects made marginally less errors when they had eaten the snack than when they had consumed the non-caloric diet soda ($df=1, 7$, $F=4.76$, $p<0.07$) (Table 9). The lunch condition did not affect either reaction time or numbers of errors in detection.

Analyses of variance performed on each of the above tasks using the four experimental weeks of participation revealed no significant practice effects. Postexperimental questioning indicated that the subjects did not guess the purpose of the experiment.

Discussion

The results of Experiment 2 again demonstrated that a late afternoon nutritional snack can have positive effects on cognitive performance. Subjects recalled significantly more digits in the backward digit span test and responded significantly faster to correctly detect targets in the CPT task when they had consumed a fruit-flavored yogurt than when they consumed a diet soda. These data confirm the results of the previous experiment which employed a confectionery product as the nutritional snack. These results suggest that both types of short-term supplements may be useful in improving cognitive performance on tasks requiring sustained attention. Similar positive effects of confectionery products have been observed in female college students tested under analogous experimental conditions (Kanarek & Swinney, Note 1).

It should be noted that additional positive effects of the nutritional snack were found in the second experiment. Subjects solved significantly more arithmetic problems and solved these problems in significantly less time, and read each line of text in the reading task significantly more rapidly after eating a fruit-flavored yogurt than after consuming the diet soft drink. While these effects were not observed with the confectionery product, it is too early to determine if the two types of nutritional supplements have different effects on cognitive performance. These experiments were done in sequential order which means that the experimenters had more experience working with subjects and using the experimental equipment by the time the second experiment was conducted. This experience could have influenced the outcome of the study. Additionally, the young men in the first experiment did correctly solve more arithmetic problems when given the confectionery product snack than when given the placebo. This difference just missed reaching statistical significance. Further studies are required to determine possible differential effects of the two types of snacks.

In the present experiment, only marginal effects of lunch on cognitive behavior were observed. In Experiment 2, subjects' reading times were significantly faster after they had eaten lunch than when they had not eaten lunch. These data are in contrast to previous studies which have demonstrated a deficit in performance on some cognitive tasks following consumption of lunch (e.g. Craig, 1986; Smith & Miles, 1986 a, b; Smith *et al.*, 1988). However, in the majority of these previous studies rather different experimental designs were employed. In these studies, performance on cognitive tasks were compared before and after lunch. Ability to maintain attention after lunch generally was impaired relative to performance before lunch (Craig, 1986; Smith & Miles, 1986 a, b; Smith *et al.*, 1986). In the present studies, no determinations of prelunch performance was made. Therefore, it is impossible to determine if lunch led to a decrement in performance. However, comparison between the lunch and no lunch condition, particularly in the condition where a diet soda was used as the snack, suggest that in this situation lunch did not lead to an impairment in attentional abilities. An additional difference between the present studies and previous ones is the time of testing following lunch. Craig (1986) has pointed out that the postlunch dip in performance depends to some extent on the time between lunch and testing on cognitive tasks with maximal effects occurring 1-2 h following lunch.

Previous work investigating short-term nutritional effects on behavior has compared high-protein and high-carbohydrate foods in healthy adults (e.g. Lieberman *et al.*, 1986; Spring *et al.*, 1983, 1986). In general, subjects reported feeling less alert and more fatigue following high-carbohydrate meals than following high-protein meals. These effects were observed 1-2 h after the meal and began to diminish by 3 h after the meal. With respect to performance, subjects, on average, were slower on a simple auditory reaction time task if they had eaten a carbohydrate meal than if they had eaten a protein meal (Lieberman *et al.*, 1986). The maximum effect of the nutritional variables on the reaction time task was observed at 1.75 h following the meal. These results can be contrasted with those of the present experiments. In the present studies, a nutritional snack (confectionery product or fruit-flavored yogurt) improved performance on a visual reaction time task. The effect was observed approximately 1 h after the snack was consumed. Several factors could account for the differences between these sets of experiments. First, while confectionery products typically are perceived as high-carbohydrate foods, they do contain significant amounts of fat and also some protein. Yogurt contains minimal fat but 20% of its calories come from protein. Spring (1986) has suggested that small amounts of protein can cancel the effects of a carbohydrate rich meal. Thus, the combination of nutrients present in confectionery products and yogurt could account for the beneficial effects of these foods on cognitive performance. Second, in the previous studies, an auditory reaction time task was used while in the present studies, a visual reaction time task was used. Nutritional variables may differentially influence tasks associated with these two sensory modalities. Finally, time factors may be important in determining nutritional effects. In our studies, attention was tested approximately 1 h after subjects consumed the snack, while in the previous work it was measured 1.75 h after food intake. To determine the effect of time variables on performance, testing should be conducted at several time points after food intake.

The mechanism of the beneficial effects of nutritional snacks on cognitive behavior remain to be elucidated. Alterations in a number of physiological parameters, such as blood glucose and insulin levels (Pollitt *et al.,* 1981, 1982) or brain serotonin levels (Spring *et al.,* 1983), have been suggested as potential mediating factors. However, recent data has demonstrated that positive effects of nutritional snacks (confectionery product or bran muffin) are not observed when the snack is given in the late morning (Kanarek & Swinney, Note 1). These findings indicate that the effects of nutritional supplements on behavior may, in part, be related to endogenous circadean rhythms (see also Smith & Miles, 1986 a, b; Spring, 1986).

The preceding studies represent only a beginning of our understanding of the effects of short-term nutritional variables on behavior. There are obvious difficulties in performing these types of experiments (Kanarek & Orthen-Gambill, 1986; Spring, 1986). It is difficult to employ strict double-blind techniques, as the subjects know what they are consuming. Subjects may have particular beliefs about how a food influences their behavior and thus, bring their expectations into the experimental situation. For example, a subject may believe that a high-carbohydrate food, such as a candy bar or soda, provides them with a quick "burst of energy". In the present experiment, when questioned at the end of the study, the subjects did not know the nutritional content of the snacks nor did they accurately estimate the.caloric content of the nutritional and non-nutritional snacks. Additionally, they did not discern the exact nature of the studies. Most subjects guessed that the effects of either: (1) different types of breakfast foods, or (2) lunch were being examined. To control for experimenter bias, the experimenters administering the cognitive tasks were blind to the nutritional status of the subject. Individual differences among subjects also represent a difficulty in these studies and stress the value of within subject designs (Neims, 1986). A third problem, mentioned above, is determining the time interval between food intake and cognitive testing. Further, dose-response relations for food components have yet to be deliniated (Dews, 1989).

REFERENCE NOTE

1. Kanaek & Swinney, results of unpublished studies.

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