Northumbria Research Link

The impact of a high versus a low glycaemic index breakfast cereal meal

on verbal episodic memory in healthy adolescents

MICHAEL A. SMITH[1], & JONATHAN K. FOSTER[2,1]

[1]School of Paediatrics and Child Health, University of Western Australia, Perth, Western Australia, and [2]School of Exercise, Biomedical and Health Sciences, Edith Cowan University, Perth, Western Australia

Abstract

In this study, healthy adolescents consumed a) a low glycaemic index (G.I.) breakfast cereal meal, or b) a high G.I. breakfast cereal meal, before completing a test of verbal episodic memory in which the memory materials were encoded under conditions of divided attention. Analysis of remembering/forgetting indices revealed that the High G.I. breakfast group remembered significantly more items relative to the Low G.I. breakfast group after a long delay. The superior performance observed in the High G.I. group, relative to the Low G.I. group, may be due to the additional glucose availability provided by the high G.I. meal at the time of memory encoding. This increased glucose availability may be necessary for effective encoding under dual task conditions.

Correspondence: Michael Smith, BA (Hons), School of Paediatrics and Child Health, University of Western Australia, GPO Box D 184, Perth, Western Australia, 6840. Fax +61 8 9388 2097. Email: msmith@meddent.uwa.edu.au

Breakfast skipping is known to be more prevalent among adolescents and young adults than in other age groups (Siega-Riz et al. 1998; Siega-Riz et al. 2000). A recent review by Rampersaud et al. (2005) demonstrates the importance of breakfast consumption for cognitive performance in adolescents. Most studies in this literature have investigated the short-term effects of breakfast consumption on cognitive functioning, either in the laboratory or at school (Rampersaud et al. 2005). A number of domains of cognitive functioning have been implicated as benefiting from breakfast consumption. For example, in a within-participants study by Wesnes et al. (2003), school children aged between nine and 16 years showed a decline in attention and episodic memory performance over the course of a morning, following consumption of a) a glucose laden drink, or b) no breakfast. However, this decline in attention was significantly reduced subsequent to consumption of either of two different breakfast cereal meals.

Several studies have reported cognitive improvements subsequent to breakfast consumption (relative to fasting) in children and adolescents (e.g. Benton and Sargent 1992; Cueto et al. 1998; Wesnes et al. 2003). However, fewer studies have investigated the impact of breakfast cereal meals differing in glycaemic index (G.I.) on cognitive functioning. The G.I. is a measure of the effect that ingested substances have on blood glucose levels: high G.I. foods cause a sharp increase in blood glucose levels, followed by a sharp decline, after consumption, whereas low G.I. foods result in a smaller but more prolonged rise in blood glucose levels (Roberts 2000).

Mahoney et al. (2005) investigated the effect of i) low G.I. oatmeal, ii) relatively higher G.I. cereal and iii) no breakfast on cognitive functioning in children. These researchers employed a within-participants design to test a number of domains of cognitive functioning between one and two hours following breakfast consumption.

Test sessions took place one week apart, with participants consuming each of the three treatments over a three week period. The findings indicated that in 9 to 11 year-olds, spatial memory was enhanced subsequent to ingestion of the low G.I. breakfast cereal meal, relative to the other breakfast conditions. This same pattern was also observed on short-term memory for the female participants in this age group. In younger children aged between 6 and 8 years, consumption of a low G.I. breakfast cereal meal was found to improve spatial memory and auditory attention relative to the other conditions, while short-term memory enhancement was also observed following ingestion of the low G.I. meal for the female participants in this age group. Similarly, in a further study of children aged between 6 and 11 years, declines in accuracy of attention and secondary memory (observed following consumption of a high G.I. breakfast cereal) were found to be significantly reduced subsequent to ingestion of a low G.I. cereal (Ingwersen et al. 2007). This observation that low G.I. breakfast meals are associated with improvements in cognitive functioning has also been extended to healthy young adult participants: Benton et al. (2003) observed superior word recall performance in healthy young adult participants subsequent to ingestion of a low G.I. relative to a high G.I. breakfast meal.

Taken together, the findings of these three studies suggest that cognitive performance is improved subsequent to ingestion of a low G.I. breakfast meal, relative to a high G.I. breakfast meal, in children and adolescents. The authors of these studies suggest that these findings may be related to the prolonged availability of glucose that follows ingestion of low G.I. foods (Benton et al. 2003; Ingwersen et al. 2007; Mahoney et al. 2005). Increased glucose availability subsequent to oral glucose ingestion has been associated with improvements in cognitive functioning in a number of clinical populations suffering from cognitive deficits, the healthy elderly, and also

in healthy young adults (for a review see Messier 2004). Glucose administration has also been associated with cognitive enhancement in healthy young adults. However, this effect has been found to be most reliable under increased cognitive demand. For example, glucose has been demonstrated to enhance performance on a difficult serial subtraction task, but not on a serial subtraction task associated with a relatively lower cognitive load (Kennedy and Scholey 2000; Scholey et al. 2001). In our laboratory, glucose has only been demonstrated reliably to enhance cognitive functioning in healthy young adults during conditions of divided attention at encoding (e.g. when encoding of verbal memory stimuli takes place concurrently with a secondary motor task; Foster et al. 1998; Sünram-Lea et al. 2001; Sünram-Lea et al. 2002a; Sünram-Lea et al. 2002b; Sünram-Lea et al. 2004).

The aim of the present study was to investigate the effect of two breakfast cereals, differing in G.I. value, on a verbal episodic memory task, under conditions of divided attention at encoding in adolescents. Previous research has noted cognitive benefits subsequent to the ingestion of low G.I. breakfast meals (Benton et al. 2003; Ingwersen et al. 2007; Mahoney et al. 2005). However, in contrast, it was here hypothesised that, under conditions of heavy cognitive demand due to divided attention, a high G.I. breakfast cereal meal would improve verbal episodic memory (delayed recall) performance relative to a low G.I. breakfast cereal meal. This prediction is consistent with previous findings in our laboratory (Foster et al. 1998; Sünram-Lea et al. 2001; Sünram-Lea et al. 2002a; Sünram-Lea et al. 2002b; Sünram-Lea et al. 2004), and is predicated on greater brain glucose availability subsequent to ingestion of the high G.I. cereal meal, which may be required to fuel the brain during highly demanding dual-task conditions.

Method

Participants

Participants were 38 healthy adolescents (19 males, 19 females), ranging between 14 and 17 years of age (M_{age} = 15.6, SD_{age} = 0.9). Participants were recruited from independent and government secondary schools in Perth, Western Australia. There were no significant differences between the two treatment groups in terms of age, body mass index (BMI) and the self-reported number of days per week on which breakfast is skipped (see Table I). The purpose of collecting self-report data pertaining to breakfast skipping was to ensure comparability between the two treatment groups in terms of habitual breakfast consumption. One participant in the Low G.I. group and one participant in the High G.I. group reported being non-compliant with the overnight fasting instructions of the study. These two participants were therefore removed from the data set for all analyses, in order to avoid any potential confounds arising from a 'second meal effect'. However, whether these individuals were included in the analysis did not change the results of any of the inferential statistics reported here.

[INSERT TABLE I ABOUT HERE]

Ethics approval for the study procedure was obtained from the Scientific Advisory Sub-Committee and Human Research Ethics Committee of Princess Margaret Hospital, Perth, Western Australia. Written consent was obtained from all participants and their parents prior to the commencement of the experimental procedure.

Treatment and Design

A between-participants design was employed. There was a single between-participants factor (treatment) with two levels (low G.I., high G.I.).

The low G.I. breakfast cereal meal consisted of 30 g All-Bran ® (Kellogg's ®, Australia) served with 125 ml Brownes Dairy ® (Western Australia) Hilo milk (1.8% fat). The high G.I. breakfast cereal meal consisted of 30 g Cornflakes (Kellogg's ®, Australia) served with 125 ml Brownes Dairy ® Hilo milk (see Table II). Participants were randomly assigned to one of these two treatment groups. The addition of extra sugar or other condiments to these treatments was not permitted. Participants were required to consume all of the breakfast cereal meal that they were administered by the researchers, including the breakfast cereal and all of the milk, within a ten minute period.

[INSERT TABLE II ABOUT HERE]

Materials

Modified California Verbal Learning Test (CVLT). The modified CVLT employed here has been used previously in this area of research by Foster and colleagues (1998; Sünram-Lea et al. 2002b; Sünram-Lea et al. 2004). The modified CVLT measures immediate, short delay and long delay episodic memory for a 20-item supraspan word list. The list comprises five items from each of four semantic categories. This 20-item word list is read aloud five times to the participants, with an immediate free recall trial following each presentation of this list (List A). Immediately subsequent to the fifth immediate free recall trial, an interference list (List B) is read aloud to the participants, followed by an immediate List B free recall

trial. The CVLT additionally comprises free recall phases and cued recall phases (in which participants are provided with the semantic categories from which the items are drawn as recall cues) at a short and long delay. Details pertaining to the timing of the modified CVLT recall phases are included in the Procedure section, below.

Simultaneously with encoding of the modified CVLT word lists, participants were required to perform a secondary motor task. While this procedure was carried out in earlier previous studies to reduce the likelihood that participants would perform at ceiling levels on the modified CVLT (Foster et al. 1998), it has since been reported that the glucose memory facilitation effect is only typically observed in healthy young adults when a secondary task is administered (Sünram-Lea et al. 2002b). Participants were told that performance on the word recall task and hand movement task was equally important, and that they should aim to perform equally well on both tasks. Participants were also told that their hand movements were being recorded by a camcorder, so that the researchers could assess their performance at a later time. The camcorder was used to induce compliance with task instructions to perform both tasks equally well, although no such recording actually took place. Two different motor sequences were performed synchronously with both hands. Participants were required to perform a "fist" – "chop" – "slap" motor sequence in the 2.5 s interval between each of the first five items of the modified CVLT. Between each of the next five items of the modified CVLT (i.e. items six to ten), participants were required to perform a "back-slap" – "chop" – "fist" motor sequence. Participants were then required to revert back to the first "fist" – "chop" – "slap" sequence between items 11 and 15, and then back to the second "back-slap" – "chop" – "fist" sequence for items 16 to 20. Participants were not informed when to switch from one sequence to the other. They

therefore had to keep track of when to switch from one sequence to the next themselves.

In addition to the derivation of raw memory retention scores for each recall phase of the modified CVLT, remembering/forgetting indices were also calculated. The benefit of these derived measures is that they control for individual differences in the total items recalled in the previous recall phase. The total number of items remembered/forgotten at the short delay was calculated by subtracting the total score on the short delay free recall phase of the modified CVLT from the total score on trial five of the immediate free recall phase of the test. The total number of items remembered/forgotten at the long delay was calculated by subtracting the total score on the long delay free recall phase of the modified CVLT from the total score on the short delay free recall phase. The calculation of these indices allowed for a within-participants comparison of remembering/forgetting rates over time.

Bond-Lader Questionnaire. The Bond-Lader scale used here (Bond and Lader 1974) has also been employed in other studies investigating nutrition, mood and cognitive functioning (e.g. Wesnes et al. 2003). This instrument requires participants to rate their level of 'alertness', 'contentedness', 'calmness' and 'satiety' on 19 bipolar scales. Three additional items were added to the original Bond-Lader scale for the purpose of the present study, in order to investigate self-reported fluctuations in satiety throughout the test session. The ratings were made by placing a mark at the relevant point on a 100 mm line, with the end of each line reflecting the relevant extremes of the dimension being rated (e.g. 'alert' versus 'drowsy'). The Bond-Lader scale used in this study is considered to be a useful measure of moment-to-moment fluctuations in mood and affect. A higher score indicates a higher level of the relevant

dimension. This application of the Bond-Lader scale is consistent with previous work (e.g. Wesnes et al. 2003).

Blood Glucose Equipment. Blood glucose concentration was measured using a MediSense Optium Blood Glucose Meter, MediSense Optium Point-of Care Disposable Blood Glucose Test Strips and a MediSense Auto-Lancing Device with thin lancets (Abbott Diagnostics Division, Doncaster, Victoria, Australia). One drop of capillary blood was obtained from the fingertip of each participant for each measurement of blood glucose using the lancing device. The consistency and accuracy of MediSense Blood Glucose Meters has been reported to be very high (Matthews et al. 1987).

Procedure

Participants were instructed to fast from 10:30 pm on the evening prior to testing. Written informed consent had been obtained previously from participants and their parents. All test sessions began between 8:00 and 8:30 am. Participants were tested in groups in a standard classroom setting. Participants were weighed, and measurements of their height were obtained. Participants then completed the Bond-Lader questionnaire and their baseline blood glucose concentrations were measured. Following the measurement of blood glucose concentrations, participants consumed one of the two treatments, depending on the treatment group to which they had been randomly assigned (Low G.I., High G.I.). Participants were allowed ten minutes to consume their designated treatment. Ten minutes following the completion of cereal consumption, blood glucose concentrations were measured for the second time and participants were again administered the Bond-Lader questionnaire. Participants then completed the immediate free-recall trials of the modified CVLT (List A, trials 1 -5),

followed by the modified CVLT interference list (List B). Hand movement sequences were performed during encoding of each modified CVLT word list. Fifty minutes post-treatment delivery, participants were administered the third Bond-Lader questionnaire, and a third measurement of blood glucose concentration was obtained. Following this, participants completed the short delay recall phases of the modified CVLT. Following a short break, the final measurements of blood glucose concentrations were recorded, and the final Bond-Lader questionnaire was administered to the participants 90 minutes post-treatment delivery. The long delay recall phases of the modified CVLT were then completed. Following the completion of the testing procedure, participants were offered a further breakfast cereal meal before they returned to normal school classes. The testing procedure is outlined in Table III.

INSERT TABLE III ABOUT HERE

Results

Blood Glucose Concentrations

A significant main effect of time was observed, $F(3, 32) = 33.25$, $p < .001$, with the effect size being large (partial $\eta^2 = .76$). Post-hoc pairwise t-tests revealed that blood glucose concentration, collapsed across both treatment groups, was significantly higher ten minutes post-treatment delivery, $t(35) = -6.65$, $p < .001$, and 50 minutes post-treatment delivery, $t(35) = -5.12$, $p < .001$, than at baseline. Blood glucose concentrations, collapsed across both treatment groups, did not differ from baseline 90 minutes post-treatment delivery. The time x treatment interaction failed to reach significance (see Figure 1).

[INSERT FIGURE 1 ABOUT HERE]

Bond-Lader Scale

A significant main effect of time was observed on the alertness subscale, $F(3, 32) =$ 7.44, $p = .001$, with the effect size being moderate (partial $\eta^2 = .41$). Post-hoc pairwise t-tests revealed that self-rated alertness, collapsed across both treatment groups, was significantly higher than baseline at ten minutes post-treatment delivery, $t(35) = -4.41$, $p < .001$, at 50 minutes post-treatment delivery, $t(35) = -2.74$, $p = .01$, and at 90 minutes post-treatment delivery, $t(35) = -3.22$, $p < .01$.

A significant main effect of time was observed on the satiety subscale, $F(3, 32) = 2.95$, $p < .05$, with the effect size being moderate (partial $\eta^2 = .22$). Post-hoc pairwise t-tests revealed that self-rated satiety, collapsed across both treatment groups, was significantly higher than baseline at ten minutes post-treatment delivery, $t(35) = -2.51$, $p < .05$.

The main effect of time failed to reach significance of the contentedness and calmness subscales. Further, the time x treatment interactions failed to reach significance on the alertness, calmness, contentedness and satiety subscales of the Bond-Lader questionnaire.

Modified CVLT

Immediate, Short and Long Delay Recall. No significant effects of treatment were observed on any of the free or cued recall phases of the modified CVLT (see Table IV).

[INSERT TABLE IV ABOUT HERE]

Remembering/Forgetting Indices. As detailed in the Method section, above, remembering/forgetting indices were derived for each participant from the modified CVLT retention scores. Because of floor effects, a remembering/forgetting index was not able to be calculated for one participant from the High G.I. breakfast cereal group who scored 0 on trial 5 of the immediate free recall phase. Therefore, only 35 participants were included in this analysis.

There was a main effect of delay on remembering/forgetting rates, in that there was a trend of greater remembering at the long delay, relative to the short delay (i.e. a reminiscence effect), $F(1, 33) = 5.89$, $p < .05$, but the effect size was small (partial $\eta^2 = .15$). The time x treatment interaction was also significant, $F(1, 33) = 5.89$, $p < .05$, with a small effect size (partial $\eta^2 = .15$). With respect to this later interaction, post-hoc t-tests revealed i) significantly more items were remembered at the long delay, relative to the short delay, for those individuals who consumed the high G.I. breakfast cereal meal, $t(15) = 2.71$, $p < .05$, and ii) significantly more items were remembered for the High G.I. group, relative to the Low G.I. group, at the long delay, $t(33) = -2.34$, $p < .05$ (see Figure 2).

[INSERT FIGURE 2 ABOUT HERE]

Discussion

The aim of the present study was to investigate the impact of a low, versus a high, G.I. breakfast cereal meal on verbal episodic memory functioning in healthy adolescents, under conditions of divided attention at encoding. On the basis of

previous research demonstrating that glucose reliably facilitates verbal episodic memory functioning in healthy young adults only under conditions of divided attention (Sünram-Lea et al. 2002b), it was hypothesised that greater verbal episodic memory performance would be observed in the present study subsequent to ingestion of a high G.I. breakfast cereal meal, relative to a low G.I. breakfast cereal meal. Although inconsistent with some previous findings which have investigated the effects of breakfast consumption on cognition (Benton et al. 2003; Ingwersen et al. 2007; Mahoney et al. 2005), this hypothesis is consistent with the notion that a rapid supply of glucose to the brain may be necessary to observe memory enhancement under conditions of divided attention at encoding.

Blood glucose concentration and self-reported alertness, contentedness, calmness and satiety did not differ significantly between the two treatment groups evaluated in this study. Further, no significant differences between the Low G.I. and High G.I. groups were observed on either recall phase of the modified CVLT. However, analysis of the forgetting/remembering indices that were computed indicated that i) the High G.I. group remembered significantly more items after the long delay, relative to the short delay, and ii) the High G.I. group remembered significantly more items after the long delay than the Low G.I. group. It is of interest that in the present study, the High G.I. group recalled significantly fewer items at the short delay than immediately after encoding, but remembered a greater proportion of these items at the long delay (relative to the short delay). A similar effect was not seen in the Low G.I. group, in which the number of items recalled reduced progressively at each recall phase.

The pattern in which non-recalled items in a memory test are recalled at a later recall phase is known as 'reminiscence' (Smith and Vela 1991). Reminiscence is a

phenomenon by which memory recall leads to output interference, in that the memory trace for recalled items is strengthened, while the memory trace for non-recalled items is weakened. However, this output interference reduces with time; therefore, non-recalled items from previous recall phases may be recalled at later recall phases (Smith and Vela 1991). It is possible that a reminiscence effect was observed for the High G.I. group in the present study.

A further potential explanation of the finding that the high G.I. group exhibited enhanced remembering at the long delay as they were able to use the recall cues provided at the short delay cued recall phase more effectively at long delay free recall. Remembering/forgetting indices are very valuable in studies such as this, as they represent an indication of within-participants effects of treatment on memory over time (i.e. controlling for recall performance at the previous recall phase). However, measures of delayed memory performance reflected by these indices are likely to be influenced by the short delay cued recall task that takes place on the CVLT. This short delay cued recall task occurs between the short delay and long delay free recall tasks that are used to calculate the long delay remembering/forgetting index. It would be of interest to investigate further in future investigations of memory functioning following breakfast intake the extent to which the relationship between G.I. and remembering of verbal information is due to the effectiveness of recall cue use or due to reminiscence.

The finding that verbal episodic memory performance was greater after the long delay for adolescents who consumed the high G.I. breakfast relative to the low G.I. breakfast cereal meal is inconsistent with some previous findings reported in children (Ingwersen et al. 2007) and adults (Benton et al. 2003). Both of these previous studies reported episodic memory benefits associated with the consumption

of a low G.I., relative to a high G.I. breakfast cereal. However, in both of these studies memory encoding did not take place under conditions of divided attention, as was the case in the present study. Previous research in the glucose and cognition literature suggests that glucose is only reliably observed to facilitate verbal episodic memory processing in healthy young adults under conditions of divided attention at encoding (Sünram-Lea et al. 2002b). Therefore, it is possible that a higher supply of glucose to the brain is required during more demanding dual task conditions to facilitate cognition. This proposal would appear to account well for the findings observed in the present study.

However, there is one limitation with the notion that the better performance in the High G.I. group was due to the higher supply of glucose delivered to the brain. In the present study, blood glucose concentration was not observed to be higher for the High G.I. group, relative to the Low G.I. group, at any of the time points at which blood glucose concentration was measured. In the present study, blood glucose concentration was measured ten minutes post-treatment, with the next measure taking place 50 minutes post-treatment consumption. This procedure was undertaken to ensure that memory encoding was taking place at the time that blood glucose would be expected to peak subsequent to consumption of a high G.I. meal (20-40 minutes post-treatment consumption; Roberts 2000). It is therefore likely that, during the period at which blood glucose concentration peaked in the high G.I. group, participants were undergoing cognitive testing (i.e. blood glucose concentration was not measured at this time).

The present research has improved upon previous studies investigating the impact of G.I. of breakfast meals on cognition in children. Previous studies (e.g. Ingwersen et al. 2007; Mahoney et al. 2005) have neglected to measure blood glucose

concentration during the test session itself. However, future work could improve on the methodology employed here by ensuring that blood glucose concentrations are monitored more regularly, specifically (wherever possible) at the time point when blood glucose concentration is likely to peak. Given that this was not the case in the present study, differences in glycaemic regulation between the two treatment groups could have contributed to the lack of significant between group differences in blood glucose concentration across the high G.I. and low G.I. treatment groups observed here. It is, of course, impossible to rule out whether any further inter-individual confounding variables may be responsible for the present study findings, owing to the between-subjects methodology employed.

While no significant differences were observed between the two treatment groups on any of the Bond-Lader scales, self-ratings of alertness were found to be higher than baseline for both treatment groups across the test session, following breakfast consumption. This finding suggests that consumption of a breakfast cereal meal can elevate and maintain feeling of alertness subsequent to an overnight fast, regardless of the G.I. of the meal. Self-ratings of satiety also increased for both treatment groups in the period immediately subsequent treatment consumption. This finding demonstrates that consumption of a breakfast cereal meal is effective in reducing feelings of hunger in adolescents subsequent to an overnight fast, at least for a short period, subsequent to ingestion of a breakfast meal. It is somewhat surprising that in the present study, there were no differential effects of the two breakfast cereal meals on satiety. It has been reported previously that low G.I. foods are associated with increased satiety relative to high G.I. foods (McMillan-Price and Brand-Miller 2006). Taken together with the lack of significant difference in blood glucose

concentration observed between the two treatment groups, this finding raises issues related to the treatment manipulation used in the present study.

An improvement of this study, in contrast to previous studies of breakfast on memory performance in children, is that the two breakfast cereal meal treatments were more closely matched in terms of macronutrient composition than in previous studies (e.g. Ingwersen et al. 2007). A limitation of the current investigation, and of this area of research more generally, is that the differences in energy, protein, fat and carbohydrate concentrations between different commercially available breakfast cereal products make it difficult to control for the influences of nutritional components other than G.I. on cognitive outcome. It is possible that the differences between these two breakfast cereal meals other than G.I contributed to the difference in memory performance between the two treatment groups observed here. Further, expectancy effects related to ingested substances are known to influence cognitive performance (Green et al. 2001), and may have implications for the present study findings.

A further limitation when interpreting the findings of the present study concerns the lack of significant treatment effects on any of the CVLT tasks. It would also be of value in future studies to incorporate a divided attention control condition in which memory materials are encoded under single task conditions only. This design would enable an evaluation of whether the findings observed in the present study are due to the higher supply of glucose to the brain provided by the high G.I. meal in the specific context of a dual task paradigm, or whether some other explanation may better account for the findings reported here.

To summarise, in the present study consumption of a high G.I. breakfast cereal was associated with reduced forgetting of previously encoded verbal episodic memory

materials, relative to consumption of a low G.I. breakfast cereal, under conditions of heavy cognitive demand during encoding. This finding is potentially related to the more rapid supply of glucose to the bloodstream, subsequent to consumption of a high G.I. meal. Specifically, the more rapid delivery of glucose offered by a high G.I. meal may be necessary to fuel the brain optimally under dual task conditions, conferring subsequent benefits on memory functioning. This suggestion warrants further investigation in future studies.

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Table I

Means and standard deviations of age (in years), BMI, and the average number of days per week on which participants reported skipping a breakfast meal for the Low G.I. and High G.I. breakfast cereal meal treatment groups. There were no significant differences between the two groups on any of these variables.

	Low G.I.		High G.I.		
	M	*SD*	*M*	*SD*	*p*
Age (years)	15.6	0.9	15.7	0.9	*n.s.*
BMI	22.3	3.6	20.7	2.8	*n.s.*
Average days / week breakfast skipped	0.8	1.4	0.8	1.8	*n.s.*

Table II

The nutritional composition of the two breakfast cereal meal treatments. Values for

protein, fat and carbohydrates are in grams.

Treatment	Calories	Protein	Fat	Carbohydrates (Sugar)	G.I.[a]
Low G.I.	158	8.8	2.8	20.5 (10.2)	30
High G.I.	172	6.5	2.0	31.2 (8.5)	77

[a]G.I. values reported in this table are based on the G.I. values for All Bran (Kellogg's,

Pagewood, Australia) and Cornflakes (Kellogg's, Australia) reported by Foster-

Powell, Holt and Brand-Miller (Foster-Powell et al. 2002).

Table III

The study procedure (the time in minutes of each procedure prior/subsequent to

treatment delivery is displayed in the left column).

t (mins)	Procedure
-15	Measurement of height and weight
-10	First blood glucose measurement
	First Bond-Lader Scale administration
0	Corn Flakes meal administered to high G.I. group
	All Bran meal administered to low G.I. group
10	Second blood glucose measurement
	Second Bond-Lader Scale administration
20	CVLT Immediate Free Recall (List A, five trials) with secondary motor task
	CVLT Immediate Free Recall (List B) with secondary motor task
50	Third blood glucose measurement
	Third Bond-Lader Scale administration
60	CVLT Short Delay Free Rcall
	CVLT Short Delay Cued Recall
90	Fourth blood glucose measurement
	Fourth Bond-Lader Scale administration
100	CVLT Long Delay Free Recall
	CVLT Long Delay Cued Recall

Table IV

CVLT results for the High G.I. breakfast cereal and Low G.I. breakfast cereal treatment groups. There were no significant differences between

the two groups on any of the modified CVLT recall phases.

	Low G.I.		High G.I.			
Modified CVLT recall phase	*M*	*SD*	*M*	*SD*	*p*	Partial η^2
Immediate free recall List A (trial 5)	15.5	2.1	13.8	4.4	*n.s*	.06
Immediate free recall List B	7.7	3.2	5.9	3.2	*n.s*	.08
Short delay free recall	15.1	2.9	13.1	3.4	*n.s*	.10
Short delay cued recall	15.2	2.8	14.6	3.2	*n.s*	.01
Long delay free recall	14.7	2.7	14.3	2.8	*n.s*	.01
Long delay cued recall	15.3	2.7	15.7	3.0	*n.s*	.01

Figure 1

Mean blood glucose concentration for the high G.I. breakfast cereal group and the low G.I. breakfast cereal group 10 minutes prior to treatment delivery (baseline), and 10, 50 and 90 minutes following treatment delivery (± S.E.). Blood glucose concentrations, collapsed across both treatment groups, were significantly higher than baseline a) ten minutes and b) 50 minutes post treatment delivery.

Figure 2

Mean number of items remembered/forgotten throughout the test session for the Low G.I. breakfast cereal meal group and the High G.I. breakfast cereal meal group (± S.E.). The number of items recalled, collapsed across both groups, was greater following the long delay relative to the short delay. There was also a significant time x treatment interaction effect, in that those participants who consumed the high G.I. breakfast cereal meal recalled significantly more items following the long delay than following the short delay. Further, at the long delay, significantly more items were remembered by High G.I. group, relative to the Low G.I. group.