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Short communication

Grazing, cognitive performance and mood

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ABSTRACT

Two experiments were carried out to examine how spreading food intake between either two or four occasions would affect mood and cognition. The first experiment used 96 participants in a between subject design where participants received either two milkshakes at 09:00 and 13:00 or four (half nutrient content but same volume) milkshakes at 09:00, 11:00, 13:00 and 15:00. The results showed that verbal reasoning accuracy improved in the four-milkshake condition. The second experiment used 24 participants in a cross-over design. The breakfast and lunch were halved in one condition and not in the other so participants either ate breakfast and lunch, or four meals at the same times as experiment 1. Verbal reasoning accuracy was improved by spreading the intake over four meals such that errors were reduced by between 30 and 40%. Speed was also increased in a five-item (but not one-item) search task. Further research is now necessary to uncover the mechanisms that underlie these effects.

Introduction

Grazing can be considered as eating small and frequent meals. Some research has examined the effects of grazing and this has shown beneficial effects on physiology (Jenkins et al., 1989; McGrath & Gibney, 1994), health (Powell, Franks, & Poulter, 1999) and weight control (Gatenby, 1997), although it may have negative effects, for example, on dental health (Morita et al., 2006). A trend toward grazing rather than restricting food intake to larger meals was noted some years ago (Traill, 1994), although a review (Kanarek, 1997) found no literature on grazing, mood and mental performance. This lack of information on the topic has not changed; an examination of the effect of grazing on mood and performance is therefore timely. It is important to distinguish between the addition of snack foods between breakfast and lunch (which, at least, adds to the day's energy intake) and "grazing" whereby there are more frequent smaller meals with no overall increase in food intake. Studies of the effects of missing meals are of relevance to the issue of the importance of frequency of consuming food. Another type of relevant study involves investigation of the effects of meal size on mood and cognitive performance. However, the available evidence gives no clear indication of the effect of meal size on mood or performance (e.g. Michaud, Musse, Nicolas, & Mejean, 1991; Smith, Ralph, & McNeill, 1991; Smith, Kendrich, Maben, & Salmon, 1994; Wyon, Abrahamsson, Järtelius, & Fletcher, 1997). This may in part be due to the different populations tested. For example, Wyon et al. (1997) tested the effect on children aged 10 who may respond differently.

This paper presents two experiments that have kept food intake constant but compared the acute effects of eating two meals (breakfast and lunch) with effects of consuming four meals (at two hourly intervals) on mood and performance over the working day.

Experiment 1

The aim of this experiment was to examine the effect of giving the same overall nutrient intake in four- or two-milkshake drinks on mood and cognitive performance. A wide range of tasks were used, as the possible effects of grazing are not established. The tasks chosen were those that have typically been used in studies of the effects of meals or macronutrients.

Method

Participants

Participants were recruited following response to a poster outside the Occupational and Health Psychology Unit. Ninety-six participants were recruited from the population of students from the University of Cardiff (mean age: 26 years, range: 18–65 years; males: $n = 36$, females: $n = 60$).

Design

A mixed design was used where there was one within subject factor (time of day) and one between subject factor (number of

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Table 1
Macronutrient content and energy given in the two- and four-drink conditions (shown for a 75 kg person).

Macronutrient	Macronutrient ratio (%)	Total content (g)	Macronutrient content in each drink in the two-drink condition (g)	Macronutrient content in each drink in the four-drink condition (g)
Protein	20	43.0	21.5	10.9
Carbohydrate	55	116.8	58.4	29.2
Fat	25	50.4	25.2	12.6
Energy		4592 kJ (1077 cal)	2296 kJ (539 cal)	1148 kJ (269 cal)

nutrient drinks). In the two-milkshake condition water was consumed instead of a milkshake on two occasions (the quantity consumed was not recorded as all participants could drink water *ad libitum* throughout the testing period to avoid thirst).

The milkshake

The macronutrient content of the milkshakes was 20% protein, 55% carbohydrate and 25% fat. The volume of each drink given varied depending on participant's weight; the milkshake was given at 4 ml/kg body weight, so for a 75 kg person, the drink volume was 300 ml. Each of the drinks in the two-drink condition contained half the total macronutrient whereas each drink in the four-drink condition contained 25% of the total macronutrient. Table 1 shows the macronutrient content of each drink given to a 75 kg person in the two-drink and four-drink conditions.

Procedure

Written informed consent was obtained from participants and ethical approval given by the Cardiff University, School of Psychology ethics committee. Before the testing day participants were familiarised with the procedure and the test battery by performing a shortened version of the tests they would be presented with on the test day. This was done so that participants were able to perform the tasks correctly on the testing day and also to remove the initial practice effect of learning how to do the tasks. On the testing day, participants arrived at the unit at 08:00 for their baseline tests, having abstained from caffeine and alcohol for at least 7 h, having had no breakfast that morning and having done no strenuous exercise. Up to eight participants were tested simultaneously and each test session lasted approximately 50 min. Participants consumed a milkshake drink at 09:00 and 13:00 or at 09:00, 11:00, 13:00 and 15:00. Subsequent tests were taken at 10:00, 12:00, 14:00 and 16:00. Participants were free to leave the lab between sessions but were instructed not to eat or drink anything between sessions.

Mood and performance tests

The following tasks were chosen as they had previously been used to examine the effects of meals (details of the tests are given in Hewlett & Smith, 2006); visual analogue mood scales measuring alertness, hedonic tone and anxiety were given before and after the performance tasks (after Herbert, Johns, & Dore, 1976), free recall of a list of 20 words (Smith, Sturgess, & Gallagher, 1999), choice reaction time tasks involving focused attention and categoric search (Broadbent, Broadbent, & Jones, 1986), a variable foreperiod simple reaction time task (Smith et al., 1999), a verbal reasoning task (Baddeley, 1968), a cognitive vigilance task (Smith et al., 1999), a semantic memory task (Baddeley, 1981), delayed recognition memory (Smith et al., 1999).

Results

Analyses of covariance were carried out (using SPSS) on the data with the baseline session used as a co-variate. Testing session was the within subject variable and four or two drinks the between subject variable. Some data were excluded from analyses in two tasks because of incorrect completion of the task. There were 6 exclusions from the semantic memory task and 13 from the verbal reasoning task. All other data from these participants were used in the analyses for other tasks.

The only performance measure showing a significant main effect of number of milkshakes was accuracy of verbal reasoning ($F(1, 80) = 4.3$, $p < 0.05$) where those in the four-milkshake condition made more correct responses than those in the two-milkshake condition (Table 2—this was unaffected by the inclusion of sex as a between subject variable). There was no significant interaction with session. In the two-milkshake condition there were on average 10% errors on the verbal reasoning task, while in the four-milkshake condition there was a mean of 5.9% errors. Spreading the drinks reduced the error rate by approximately 41%.

There were no other main effects of milkshake frequency (see Table 2), although there were a few meal frequency by session interactions. Simple effects analyses with Bonferroni corrections were carried out for the variables where frequency by session interactions were obtained: the focused attention task RT, free recall number correct, and free recall commission errors. In the analysis of the focused attention task RT, the effect of number of milkshakes was significant in the 14:00 session, where those in the four-drink condition were slower ($p = 0.007$). In the free recall task more words were correctly recalled in the four-drink condition at 16:00 ($p = 0.036$). There were also fewer commission errors in the four-drink condition at 16:00 ($p = 0.030$). However, the analyses also showed significantly more commission errors in the four-drink condition at 14:00 ($p = 0.026$).

Table 2
Mean (S.E.) scores for performance variables by session (adjusted from ANCOVA with baseline scores as covariates).

Variable	Testing time	Two drink	Four drink
Focused attention mean RT (ms)	10:00	384.0 (3.5)	388.8 (3.3)
	12:00	382.3 (3.2)	385.7 (3.0)
	14:00	370.4 (4.4)	387.1 (4.1)
	16:00	379.8 (4.7)	386.8 (4.4)
Free recall number correct	10:00	8.3 (0.4)	8.4 (0.3)
	12:00	9.8 (0.4)	10.6 (0.4)
	14:00	9.9 (0.5)	8.8 (0.5)
	16:00	8.2 (0.4)	9.3 (0.4)
Free recall commission errors	10:00	1.4 (0.2)	1.1 (0.2)
	12:00	1.3 (0.2)	0.9 (0.2)
	14:00	0.9 (0.2)	1.6 (0.2)
	16:00	3.1 (0.2)	2.4 (0.2)
Verbal reasoning %correct	10:00	88.8 (0.9)	91.3 (0.8)
	12:00	89.1 (1.2)	92.0 (1.0)
	14:00	89.1 (1.2)	92.4 (1.1)
	16:00	88.3 (1.4)	91.8 (1.2)

Discussion

This first experiment found improved verbal reasoning accuracy in the grazing condition. As there was no interaction with session it is likely that the effect is due to the spread of nutrients. Free recall was affected in the second half of the testing period although the trend in the data suggest the better recall was associated with the higher energy intake (i.e. at 16:00 in the four-drink condition and at 14:00 in the two-drink condition). This might represent an effect of blood glucose level on memory although one would expect this to be evident at the first session and it was not. Reaction time in the focussed attention task was quicker in the two-drink condition, though only at the 14:00 session. Given the number of reaction time measures that showed no effect of drink frequency this may be a chance result.

The task most consistently affected by drink frequency was the verbal reasoning task, which involves working memory and is arguably the most complicated of the tasks used. The reliability of this effect was examined in the second study. There were various limitations to experiment 1. Participants did not remain in the laboratory for the entire time period (this was impractical for many participants given the study lasted from 08:00 to 17:00) so compliance could not be guaranteed. In addition, consumption of milkshakes did not reflect normal dietary intake in the participants and an alternative method was used in the second study.

1. Experiment 2

The second experiment had the same aim, to examine the effects of the spread of food intake on mood and cognitive performance. This was done using two versions of a search task; a simpler one-item task and a more complex five-item search task and the same verbal reasoning task reported above. Two eating regimes were compared, one involving eating at frequent intervals and the other eating only breakfast and lunch. The two regimes involved the same food, with it being sub-divided into smaller portions in the grazing condition. This differed from the above experiment in that the intake was solid food rather than a milkshake, and was food of the participants' own choice.

Method

Participants

Twenty-four members of the general public (mean age 32 years, range 19–50 years; males: $n = 10$, females: $n = 14$) were recruited from local businesses.

Design

A cross-over design was used with volunteers carrying out both conditions in a counter balanced order approximately 1 week apart.

Procedure

At recruitment participants were provided with information about the nature of the study and signed a consent form. In the two meals condition breakfast was consumed at 9:00 and lunch at 13:00. In the four-meals condition the breakfast was halved and each half eaten at 9:00 and 11:00. Similarly, lunch was halved and each half eaten at 13:00 and 15:00. On each day volunteers carried out performance tests and rated their mood at 08:45, 10:30, 12:30, 14:30 and 16:30. All participants were asked to consume breakfast, consisting of cereal or toast, and a sandwich-based lunch. They were asked to select foods that could easily be divided in half for use in the four-meals condition. Individuals were given a free choice in the specific cereals or sandwiches that they chose.

Table 3
Mean scores for performance variables by session (scores are the unadjusted means from the analysis of covariance).

Variable	Testing time	Two meals	Four meals
Five-item visual search speed (number of lines completed)	10:30	11.5 (0.8)	12.8 (0.8)
	12:30	12.8 (0.7)	14.0 (0.7)
	14:30	11.0 (0.6)	13.0 (0.8)
	16:30	12.6 (0.6)	13.5 (0.7)
Verbal reasoning (accuracy – %correct)	10:30	92.8 (1.4)	95.2 (1.0)
	12:30	88.7 (2.5)	94.6 (1.4)
	14:30	89.4 (1.6)	93.2 (1.3)
	16:30	89.1 (1.8)	93.0 (0.9)

Participants were asked not to eat any other foods or consume caffeinated drinks during the test period. Similarly, they were asked to follow the same routine on both test days. Prior to the study volunteers were given a practice session to familiarise them with the tasks. Testing occurred in the normal working environment (in quiet rooms) and participants were tested in groups of four to six.

Mood and performance tests

At each testing session participants carried out paper and pencil versions of the following tasks; visual analogue mood task (after Herbert et al., 1976), single item search task (Folkard, Wever, & Wildgruber, 1983), five-item search task (Folkard et al., 1983), verbal reasoning task (Baddeley, 1968).

Results

Analyses of covariance were conducted (using the BMDP statistical package) with the baseline measures used as covariates. The analyses distinguished order of conditions, meal conditions and test time. Analyses of the mood ratings showed that the four-meal condition was associated with greater alertness and a more positive mood but these effects failed to achieve significance. Similarly, there were no significant effects of meal condition in the analyses of the one-item search task. However, both the five-item search task and the verbal reasoning task showed better performance in the four meals condition (see Table 3). The effect of meal condition was significant for five-item search speed ($F(1, 21) = 15.16$, $p < 0.0005$). This effect was also evident for accuracy in the verbal reasoning task ($F(1, 21) = 14.44$, $p < 0.001$), where there was an error rate in the two-meal condition of 11.1% while in the four-meal condition it was 7.9% (spreading meals resulted in an approximate 30% reduction in error rate).

Discussion

The aim of these experiments was to determine any effect of meal frequency on subjective mood and a range of performance measures. Previous research has shown better mood and memory following breakfast (Benton & Parker, 1998; Benton & Sargent, 1992; Smith et al., 1994) while studies of meal size revealed mixed results (Michaud et al., 1991; Wyon et al., 1997). Previous research has also shown alertness and sustained attention to be worse following lunch and again mixed results regarding meal size (Christie & McBrearty, 1979; Smith, Leekam, Ralph, & McNeill, 1988; Smith et al., 1991,1994).

Both of the reported experiments found that grazing was associated with better performance in the verbal reasoning task, while the second also found a benefit of grazing on the five-item search task. These two tasks both involve working memory and could be considered the most cognitively demanding of the tasks

presented and this provides an easily tested hypothesis for future research. The mechanism that underlies this effect is unclear. One possibility is that there is a more constant level of blood glucose when grazing and that this may play a role in improving working memory. Further research should now be carried out to determine the mechanisms underlying such effects and the practical implications of adopting a grazing habit for work and educational performance.

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