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Aversive viscerally referred states and thirst accompanying the sating of hunger motivation by rapid digestion of glucosaccharides

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Abstract

Associative conditioning of satiety indicates that concentrated maltodextrin (cMD) may induce a mildly aversive visceral signal within 20 minutes of its ingestion, as well as satiating normally. Individuals' awareness of this adverse state was tested on ratings of factorially distinct descriptions of factors liable to suppress hunger, whether distressing or comfortably satisfying. Wanted amount of a food and the pleasantness of eating it correlated highly for each of five foods, once again refuting the widespread presumption that "pleasant" refers to sensory pleasure; hence, as previously, suppression of hunger was measured as reduction of the averaged pleasantnesses of functionally related foods. At 20 minutes after the start of ingestion of a small meal on a near-empty stomach, cMD reliably reduced hunger. The greatest influence on hunger, besides normal sating, was thirst, but there were also tendencies to nausea and bloat, although all less than after a full sized meal. Visceral processes shortly after a meal can create dissociable conscious states, only one of which is satiety for food.

Keywords: hunger; sating of hunger; oversatiation; thirst; visceral distress; hypertonicity; maltodextrin.

Introduction

Remarkably little is known of the postgastric states signalled to the human brain shortly after eating. Physiological processes during this period are not directly involved in either the termination of the meal just ended or the onset of the next bout of eating, unless the meal is protracted or followed unusually quickly by some snacking or even another meal (Higgs, Williamson, Rotshtein & Humphreys, 2008; Rozin, Dow, Moscovitch & Rajaram, 1998). Nevertheless, short-term appetitive or aversive consequences of eating could act associatively to produce conditioned sensory preferences or aversions or visceral state-dependent sensory appetites or satieties (Booth, 1985, 2009a). Yet there is very little evidence on which postingestional effects condition sensory facilitation or inhibition of eating in human subjects (Brunstrom, 2004). It is important to know if visceral effects of eating come to consciousness because at least some forms of human associative learning require awareness of contingencies. The experiment reported here is the first to explore objectively the variety of conscious states referred to the viscera that arise while a high concentration of a starch product is being digested, producing effects that condition down the size of future meals like the one just eaten (Booth, Lee & McAleavey, 1976; Booth, Mather & Fuller, 1982).

Starch has been abundant in the human diet since the advent of agriculture. The glucose released by its digestion has several motivating and associative effects, evidenced experimentally in human beings and other species. The present paper focuses on the motivational effects of high concentrations of glucose generated briefly by the final step in the digestion of glucosaccharides -- namely, the breakdown of maltose within the wall of the small intestine. This transient signal to the brain can condition down both the amount eaten and also rated appetite in the case of a specific food eaten while the stomach is moderately full (Booth *et al*., 1976, 1982; Booth, Gibson, Toase & Freeman, 1994; also experiments in monkeys and rats -- see review by Booth, 2009a).

The experiment reported in this paper had a specialised aim as well. We wanted to see if a rapidly digested derivative of starch used in much previous work on learnt eating might serve in a single-session test of an individual for a signal to the brain from the digestive tract that suppresses eating (Booth, 2008). Deficient signaling of such visceral satiety is one possible explanation of the eating of meals in rapid succession in individuals having hippocampal amnesia (Higgs *et al*., 2008).

Previous demonstrations of satiating and satiety-conditioning effects of this starch product have had 8-16 participants and so, given the above need for an individualised application, this experiment was run with a group size in that modestly powered range. Furthermore, the findings were sought primarily in correlations across individuals in any one condition at a time, not on differences between conditions in the group mean.

Satiating actions of maltodextrin

Maltodextrin (MD) is a highly digestible starch derivative that can serve as a bland replacement for glucose when it has to be used at levels that are abrasive to the throat. MD began to be produced in bulk (Polycose(R) being a US brand name) for use in foods as a nutritive thickener and in medical products such as enteral feeds and (single-session) glucose tolerance tests. The first use in biological psychology was in experiments in which MD at low or high concentrations classically conditioned rats' preferences for foods to laboratory-cultural norms of feature intensity, not just to feature categories (Booth, Lovett & McSherry, 1972). This early example of a cognitive principle of object recognition has been abundantly confirmed in experiments with human participants (e.g., Booth & Freeman, 1993; Booth, Thompson & Shahedian, 1983; Conner *et al*., 1988; reviewed in Booth, 2007).

Directly relating to this paper, the fast release of glucose by digestion of MD above about 20 g per 100 ml generates an associatively aversive state that conditions inhibition of eating to a configural norm of a relatively full stomach and the sensory characteristics of the last food in a just ended meal (Booth, 1981, 1985, 2009a; Booth & Toase, 1983; Booth *et al*., 1994). The present experiment examined the possibility that the conditioning event (US) enters awareness in the form of verbally expressed concepts in addition to the loss of hunger, such as aversive sensations or negative affect.

The food constituent. MD is a mixture of oligoglucosaccharides manufactured from starch by enzymic or acidic hydrolysis. Low-glucose MD is only slightly sweet because it contains very little glucose and its disaccharide maltose. Unlike the polysaccharide starch, chains of up to about a dozen glucose moieties are readily soluble in water, making MD very convenient for experimental administration of dietary carbohydrate in various species (e.g., Booth & Davis, 1973; Booth & Grinker, 1993; Booth *et al*., 1976).

The slight sweetness of MD can be matched in a control food by a low level of sucrose (table sugar), for example. The non-Newtonian viscosity of higher concentrations of MD can be simulated by very low concentrations of the non-nutritive thickener, cellulose gum. Preparations of MD have the odour of the plant source of the starch from which they were made, e.g. maize in the USA and potato in the UK**;** however, this is readily masked to the human nose by the flavour of the food in which the MD is incorporated.

Digestion of MD. Human saliva contains relatively low levels of amylases (enzymes that start the breakdown of starch) and these are inactive in the acidity of the stomach. So the rapid digestion of MD begins only when it leaves the stomach and is exposed to the highly active amylases secreted into the lumen of the duodenum. These split off maltose which diffuses the short distance to the duodenal wall, where it passes through the brush border to the variety of disaccharidases that divide molecules of maltose into free glucose. The released glucose is then actively transported across the serosal membrane into the blood of the portal vein to the liver.

Normal sating by glucosaccharides. It remains to be determined which eating-inhibitory signals to the brain are generated by the ingestion of materials that include starch and other glucosaccharides. In rats there is clear evidence of a strongly sating action of glucose after it has been absorbed into the circulation and secretion of insulin has subsided (Booth & Jarman, 1976). There have long been neurophysiological data on glucose-specific sensitivity of nerve endings in the wall of the small intestine in mammals (Mei, 1985) but there is still no clear evidence whether their activation does or does not inhibit eating. Recent work on the molecular genetics of gustatory receptors in the mouth has now been extended to the wall of the small intestine, showing glucose-specific sensitivity in enteroendocrine cells having local trophic effects (Young *et al*., 2009) but possibly also signalling rapidly to the brain through intestinal innervation or secretions into the general circulation (Strader & Woods, 2005). Hormones from these cells also facilitate the actions of glucose from the blood in releasing insulin from the pancreas, which in turn may play a role in the satiating action of circulating glucose from food by actions in the liver and in the brain (Booth & Jarman, 1975).

However, glucose released behind the brush border also acts on osmoreceptors (Hunt & Pathjak, 1960; Mei & Garnier, 1986) as measured by the slowing of the rate of emptying of the human stomach by starch and by protein (Hunt & Stubbs, 1975) and the release of intestinal hormones involved in luminal and circulatory control of sodium ion levels (Kita *et al*., 1999). So a signal from the duodenal wall to the brain might be generated if glucose generating a high enough osmolarity were released from the maltose derived from cMD within ingested food.

Adverse effects. The dangerous former practice of administering hypertonic saline as an emetic may have worked through action on duodenal wall osmoreceptors. Therefore it is conceivable that sufficiently strong osmotic slowing of gastric emptying can reduce or reverse the normal pressure gradient between the duodenum and the stomach and so induce nausea.

High osmolarity draws fluid from any cell, creating discomfort if the cell is innervated, such as the rasping of the throat by a strong solution of sugar. The first few laboratory rats that self-administered orally a very high concentration of MD showed a posture characteristic of abdominal discomfort after a few minutes' delay that lasted for several minutes (Booth, 1977).

This potential for aversively motivating effects of concentrated maltodextrin (cMD) is consistent with indirect evidence in rats and in people for an aversively reinforcing or conditioning (associative) effect also of duodenal osmoreceptor action by glucose and/or maltose from cMD in the duodenum (Booth, 2009a; Booth & Davis, 1973; Booth, Mather & Fuller, 1982). The argument from these data runs as follows.

If food is ingested on an empty stomach and small intestine, it will be rapidly pumped from the stomach to the duodenum until the digestion of MD or any other food constituent has proceeded sufficiently far to slow gastric emptying to its normal prandial and postprandial range of rates (Hunt, 1960; Hunt & Stubbs, 1975). An aversively conditioning effect generated during that initial period of digestion could counter the conditioning of sensory acceptance by glucose in the small intestine which remains strong after considerable delay between the presentation of a flavour in food and the infusion of glucose into the stomach (Sclafani & Ackroff, 1994).

The evidence for a brief critical period of aversive conditioning came from a control condition for the conditioning of satiety, both in rats (Booth & Davis, 1973) and in human subjects (Booth *et al*., 1982). When the administration of cMD was delayed for around 10-15 minutes while other food was eaten, there was sufficient time for the stomach to have been slowed by digestion of that food and so the cMD was not passed quickly by itself to the duodenum. With that delay, neither species showed any sign of aversive conditioning of acceptance of the flavour at the end of the meal, indexed by reduction of intake (and, in people, of rated pleasantness). Instead there was a great increase in flavour-specific intake (and pleasantness) in tests for conditioning in brief intake at the end of subsequent meals. That increase was attributable to the conditioning of flavour preference by glucose without any competition from aversive conditioning as a result of rapid digestion of an initial bolus of cMD.

That control group's conditioned increase in sensory-specific food acceptance with delayed cMD (Booth *et al*., 1982) is evidence for glucose-conditioned preference in human subjects. Conditioning of preference was not seen when drinks were used to deliver the conditioned and unconditioned stimuli (Aherne *et al*., 1998). Nevertheless, when people are expecting reduction of hunger from the ingested material, glucosaccharide-conditioned preference is readily seen (Brunstrom & Mitchell, 2007; Yeomans *et al*., 2009). That is, the strong and delay-insensitive appetitive conditioning competes with the weak and transient aversive conditioning. Hence the conditioning of satiety may be difficult to achieve (Booth, 2009a).

Indeed, the aversive conditioning by cMD in human subjects produces only a decrease in the pleasantness of the flavour, not a shift to unpleasantness (Booth *et al*., 1994), although a genuine aversion has been seen in rats trained with a higher concentration of MD (Gibson & Booth, 2000). Furthermore, when the cMD-paired flavour is presented throughout the meal, the acquired flavour-specific inhibition of ingestion is confined to the later stages of the meal or soon after finishing (Booth & Davis, 1973; Booth & Toase, 1983; Booth *et al*., 1994; Gibson & Booth, 2000). This requirement for both the flavour and a relatively full stomach meets the criterion for configural conditioning of the creation of a third stimulus distinct from the two elements (Rescorla, 1973; see Glautier, 2008).

This sensitivity of the conditioning of flavour-fullness satiety rather than flavour preference to the timing of ingestion of cMD may make it difficult to obtain the conditioning when studying conscious aversive events while the cMD is being rapidly digested.

Simultaneous visceral discomfort and sating of appetite for food

The present experiment was designed to look for unpleasant states that might relate to the associatively aversive effects of cMD. These states have to be distinguishable from the suppression of appetite for food by cMD while it is conditioning satiety, even though they might contribute to that suppression. We pinned our hopes on the possibility that adverse effects, or at least their verbal conceptualisations, are more diverse across individuals than are satiety effects and so might be separable by correlational analysis across the group of variations among individuals.

It has been widely assumed that a distinct state is measured by each different wording for a disposition to eat and for the usual sensations at the beginnings and ends of meals. Yet ratings of pleasantness of foods, desire to eat, pangs of hunger and (absence of) fullness all move in the same direction with physiological or social manipulations of the disposition to eat (Booth *et al*., 1982) and only one major underlying variate has been found whenever factor-analysis has been carried out on such ratings (Booth, 2009b). Hence, we monitored normal sating of hunger by using only two terms to measure an hypothesised unitary appetite for food, selecting the terms to test the strongest current claim for separate states.

Berridge (1996) found a neuropharmacological dissociation in rats between movements that are general to ingestive motivation, dubbed "wanting," and the fixed action patterns specific to sweet taste that are supposed to elicit emotional pleasure (Steiner, Glaser, Hawilo & Berridge, 2001), which he called "liking." However, the movements to sweetness are represented in a subregion of the structure involved in motivating ingestive movements (Smith & Berridge, 2006). Attempts to contrast appetite for food and sensual pleasure in food in human adults have assumed that ratings of pleasantness or liking identify pleasure and not the disposition to eat, contrary to the longstanding evidence cited above. Nevertheless, there is now evidence in people for dissociation between learnt motivating and emotional effects of tasting sweetness (Booth, Higgs, Schneider & Klinkenberg, 2010).

Hence we compared ratings of the pleasantness of foods with ratings of fullness as the most contrasting measures of the same appetite for food. In addition, we tested the specificity of this motivation by asking the participants how thirsty they were.

Having confined the assessment of normal hunger and thirst to just three ratings, we could use a substantial number of terms to explore aversive states within only a few minutes. Words expressing bodily sensations, moods and other states experienced after large and small meals and drinks had been elicited in the USA (Guss *et al*., 2000). These were reduced to about twenty categories by agreement among the investigators on verbal or conceptual similarities, including the provision of both words in one question where British and American usages might differ (e.g. 'feeling sick' and 'nauseous'). After a pilot sample in the UK had reviewed these terms for comprehensibility, one word or a pair of words was used as the anchor term in each of a set of quantitative expressions of self-states having identical layout for responses.

Hypotheses to be tested

On the bases reviewed above, our main prediction was that concentrated maltodextrin would reduce rated appetite for food at about 10 to 20 minutes after ingestion but some unpleasant sensations would be experienced at the same time. We also tested the known unitary nature of hunger and its sating when rated in different words against an hypothesised diversity amongst thirst and its sating on one hand and one or more forms of discomfort on the other hand.

The design was adequate to pick out configural conditioning of satiety to the conjunction of gastric filling and flavour of the last-eaten food (Booth, 2009a). However, the delay of only 10 minutes at most between the start and the finish of the meal required to investigate immediate after-effects might not optimise the amount of aversive conditioning relative to the strong conditioning of preference.

Method

Participants

Volunteers in good health from among students at the University of Birmingham gave informed consent to six experimental days of lunchtime eating and rating tests. A total of 14 participants completed the design, 8 women and 6 men. On finishing the experiment, each participant was paid ten UK pounds or awarded the number of research participation credits within the BSc Psychology course that were appropriate to the duration of attendance.

The experiment was conducted in accord with the Code of Conduct and Ethical Guidelines of the British Psychological Society, including informed consent by each participant.

Food materials

Each lunch began with 100 ml of tomato soup, served in a china bowl at about 60^{o}C and eaten with a spoon. The soups were made from packs of Batchelor's Mediterranean Tomato powder with the addition of either maltodextrin (MD condition) or the non-nutritive thickener, cellulose gum (CG condition). The portion of soup solids used in each serving contained 21 kcal according to the information on the pack. The MD soup contained low-glucose maltodextrin (BN:AE 1873, Cerestar) at a final concentration of 18.7 grams per 100 ml (g %), with clouding agent (0.9 g %; San-A-Creme Z785, Kerry Ingredients) to compensate for the visual clearing action of the oligosaccharide. The CG soup included pregelled cellulose gum (Hercules) at 0.86 mg % and aspartame sweetener (Nutrasweet) at 1.3 mg % to match the textural and sweetening effects of maltodextrin at the concentration used in the MD soup. Participants were told that the soup was "cream of tomato", to legitimate its thick texture.

To finish the lunch, soup was followed by a dessert of low-fat yogurt of a single retail brand and type that was available in four fruit flavours (strawberry, raspberry, peach, black cherry). Yogurt of a particular flavour was presented in a large bowl containing more than the individual had eaten freely in total from two bowls of differently flavoured yogurt on a preliminary day.

Individuals' intakes of soup and yogurt were measured by differences in the weights of the food vessels and spoons before and after eating.

Ratings

Conscious states. Fourteen terms or pairs of terms for moods, general physical state or bodily sensations (without mention of location) were selected from those elicited and categorised by Guss *et al*. (2000) in the USA, after they had been pilot tested in the UK for comprehension and idiom. In the order presented, these "names for common feelings after meals" were: full; satisfied / finished; bloated / swollen; comfortable; sick feeling / nausea; sluggish / sleepy; discomfort / ache; empty / unsatisfied; contented / happy; full of air/gas / flatulent; warmth; heavy / fat; heartburn; thirsty.

The weakness or strength of each state was rated numerically against the ipsative norm of the feeling "after your usual lunch (with the same as usual scored as 10)." Each of the first eight of the 14 items was listed next to an array of the integers from "0" to "16", with zero (and "1") headed "Not at all" and "10" headed "As usual." Next beyond "16" was the word "more:" with a row of dots for writing in a larger number if applicable. The final six of the 14 items had just a short line each on which to write a number anchored on "10 = usual" if any of them was experienced. The option was provided to write in a feeling not on the list and to score it. In the event, almost invariably these six terms were all rated (albeit sometimes zero) and no extra term was elicited.

Food-specific amount and pleasantness. The names of five small food items widely used in Britain between meals were listed under the (deliberately ambiguous) question, "How much would you like to eat right now?" The foods were: a plain 'digestive' biscuit; cheese spread (one triangle) on a cracker (water biscuit); a banana; a mini Mars Bar; a doughnut. A line to write in another sort of food item was provided in case the participant might eat it right then but this option was never taken up.

For each food, the participant was asked to state "how much/little" s/he would eat if offered by itself right then, "e.g., two of that item or a quarter of the item (if only that item)" and "how pleasing a mouthful of just this item" would be, from "(+)10 = extremely pleasant" to "-10 = extremely unpleasant."

Flavour preferences. When presented with a sample of each of the four flavours of yoghurt, the participant was asked to name the flavour and then to rate "how much you would like to eat all of the yoghurt in a whole pot of each flavour for a lunchtime dessert (if it were among a full range of yoghurt flavours on offer then)" by placing a vertical mark "at the point that best represents your liking for the flavour in yoghurt at lunch" on a horizontal array of eight sets of three hyphens with two spaces between each triple, labeled "I'd NEVER choose it" at the left-hand end and "I'd ALWAYS choose it" at the right-hand end.

Design and overall procedure

Between a preliminary day and a final day, there were four experimental days, two with MD soup and two with CG soup. The two time-balanced sequences (MCCM and CMMC) were assigned to alternate participants attending for the preliminary day. Sensed and motivating differences between postingestional effects of MD and CG were measured on those four days.

Participants visited the food-testing facility on preappointed days to eat a lunch of tomato soup and as much yogurt as they wished of a fruit flavour they liked among the four available.

Each participant had one of her/his most prefered two flavours of yogurt on the days of the MD soup and the other on the CG days. The participant's preferences for the four flavours were assessed after eating the soup on the preliminary day and again on the final day. The difference between the MD-paired flavour and the CG-paired flavour in their differences in post-experimental preference from pre-experimental preference measured the associative effect of the MD on the appetite for the yogurt in the presence of a stomach partly filled by soup, i.e. the conditioning of satiety.

Daily procedures

Participants agreed to attend six sessions at lunchtime (starting between 12.00 noon and 1:30pm). They selected days on which they could have a light breakfast of similar composition each day and keep physical and social activities within similar and normal limits, with two consecutive days being allowed but not more. Participants were asked to consume breakfast no later than four hours before attending the sessions, to increase the likelihood that the stomach was effectively empty when the MD soup was eaten.

Induction day. The acceptability of tomato soup and fruit-flavoured yogurt to each participant was checked on recruiting. A preliminary session provided experience of the experimental lunches on a fixed amount of soup and and as much yogurt as wished, and also gave practice with the questionnaire instruments.

After writing a report of the timings and amounts of all food and drink consumed earlier that day, the participant ate the 100-ml portion of soup used on experimental days but as a 1:1 (v/v) mixture of the two types (CG and MD). Participants then tasted the four flavours each in a mouthful of yogurt and rated how pleasant it would be to finish an individual-sized pot right then just of that flavour. The individual's similarly most highly acceptable two flavours were identified immediately (i.e. second and third liked if the first and second differed greatly). A large bowlful of each was presented for the participant to eat as much as s/he wanted, subject to a minimum at the start of one spoonful from each. The self-state and appetite ratings were then completed from 10 minutes after the start of the soup and again from 20 minutes.

Experimental days. Each of the four experimental days began with the report of food and drink consumed earlier that day, followed by eating 100 ml of the soup of the type (CG or MD) assigned to the participant for that day. The participant then rated the "calories in the portion of soup just eaten as % of your whole usual lunch's calories," followed by eating as much as wanted of the yogurt having the flavour paired for that participant with that day's type of soup. Whether or not the yogurt was still being eaten, the participant was asked to start completing the questionnaires about self-states and appetite at 10 minutes after the first mouthful of soup had been taken, and again at 20 minutes after the start on soup.

Post-experimental day. The final day was the same as the induction day, with the two extra steps of rating preferences of each of the four flavours of yogurt and eating as much as wanted from a bowl each of the CG-paired and MD-paired flavours for that participant.

Analyses of data

Statistical analyses were carried out in SPSS16.0. The experimental design needed to develop an individualised test for a cMD-induced visceral satiety signal did not provide enough data for multi-level modelling or for repeated-measures MANOVA. We therefore used data-reduction by principal components analysis (PCA) to test the hypotheses that pleasantness measures motivation to eat, and that this is distinct from one or more states of discomfort and also from thirst. The reliability and size of effects of MD versus CG on experimental Days 1 and 2 were calculated in repeated-measures two-way ANOVAs on statistically distinct dependent variables from PCA. In analyses of intake, two outliers were deleted for any of the reported comparisons.

Differentiations among self-states as hypothesised in the Introduction were tested on each of the two days from ratings at 10 and 20 minutes after the start of ingestion of soup containing either concentrated maltodextrin (MD) or the control cellulose gum (CG). Since many of these ingestion-altered states change rapidly, it is not feasible to estimate test-retest reliability of sets of ratings that take an appreciable time to collect. Reliabilities could be approached, however, by comparing retesting after 10 minutes with the retesting on a later day. Thus, individuals' consistency in responding to each question on sensed self-state or food-specific motivation to eat was measured by product-moment correlation between 10 and 20 minutes on each of the four days and between Days 1 and 2 at each of those times (10 min, 20 min) in each experimental condition (MD, CG).

PCA of the self-state ratings yielded four factors in six of the eight conditions, the minor variations being on Day 1 at 20 minutes when MD and CG each had five factors. The component accounting for the largest proportion of the variance was generally some form of discomfort (median 27% of the variance), with a component including fullness and satisfaction coming a close second (23%). Thirst dominated the third or fourth factor (13%) and an affectively ambiguous state (such as warm or sluggish) loaded most heavily about equally often onto the other of these two more minor components (15%). These structures were used to evaluate the effects of MD on each hypothesised state.

Results

Wanted intake and pleasantness both measure motivation to eat

The amount of food wanted and the pleasantness of each of four sweet snackfoods loaded substantially (> 0.6) on the factor accounting for more variance in two-factor PCAs of the ratings of each of the five named foods in most of the eight conditions (10 or 20 minutes after the start of soup on experimental days 1 or 2 on each of MD or CG). The biscuit(s) were the most consistent in this way (7 out of the 8 sets of data). High loadings on this factor by banana (5/8), Mars Bars (4/8) and doughnut (4/8) were scattered around the conditions, whether MD or CG, on either experimental day or at either delay of measurement. Cracker and cheese usually (6/8) loaded heavily on the second factor. Therefore the measure of hunger (desire to eat) used in this paper was the pair of mean scores for pleasantness and for amount wanted of the four sweet foods whose ratings loaded on the first factor – biscuit, banana, Mars Bar and doughnut.

The specificity of motivation to eat to each of the five named items of food was tested by a five-factor PCA for each of the eight conditions. Almost invariably, how pleasant it would be to eat the food and the amount that the rater wished to eat both loaded heavily onto one factor for each food: medians across the eight conditions of the median and range of loadings for the most strongly co-loaded food on each factor, pleasantness 0.87, 0.49 to 0.97; amount 0.84, 0.44 to 0.95. This strong association between ratings of pleasantness and of the wanted amount across the five named foods refutes the widespread assumption that ratings of pleasantness measure sensual pleasure separately from wanting food to eat.

An extra hypothesis tested was that there is a unitary appetite for snackfoods shortly after the experimental meals, expressed by both wanted amount and pleasantness of eating of each of the five named foods. The first principal component before and after rotation of only two factors was examined in each experimental condition. Wanted amount or pleasantness of three or all four of the sweet foods tested had their greatest loading (of 0.5 or more) on the first factor, with no consistency across the eight datasets as to which of the sweet foods was not represented. The savoury food was generally most highly loaded on the second factor. Hence there might be a single appetite for sweet snackfoods, albeit not entirely coherent in British culture across the four foods tested here. The evidence was against a residual appetite shortly after a meal that is generic across sweet and savoury foods.

Prompt suppression of appetite for foods by maltodextrin

The effect on hunger of concentrated maltodextrin (MD condition) relative to non-nutritive texturiser and sweetener as control (CG condition) was to satiate the desire to eat food at 10 and 20 minutes after the start of consuming it in the test soup (Figure 1).

Figure 1 about here.

A reliable satiating effect of MD relative to CG was seen in the mean of the pleasantness ratings of a biscuit and of each of the three other sweet foods, at 10 minutes, $F(1,13) = 4.78$, $\eta^2 = 0.27$, $p < 0.05$, and at 20 minutes, $F(1,13) = 6.62$, $\eta^2 = 0.34$, $p < 0.025$ (Figure 1a). Unsurprisingly with this number of participants, the individual foods did not usually produce reliable differences between MD and CG. Nevertheless, for probably the commonest sweet snackfood, biscuits, the pleasantness of eating was reduced by MD relative to CG at 20 minutes after the start of ingestion, $F(1,13) = 6.29$, $\eta^2 = 0.36$, $p < 0.026$, and numerically but not statistically at 10 minutes, $F(1,13) = 1\ 86$, $\eta^2 = 0.13$, $p > 0.2$ (Figure 1b).

Set the Greek lower-case letter eta (squared) at each " η^2 " above

The other of the pair of measures of hunger (desire to eat), i.e. the wanted amounts of the four sweet foods, gave numerical effects in the satiated direction but these differences did not reach reliability when their differences in ratings of pleasantness did, either for the mean across foods or for individual foods. This lower sensitivity of wanted amounts than of pleasantness ratings, at least when averaged across foods, was also observed by Booth *et al.* (1982).

The non-sweet cracker and cheese item named, loading on a separate component, was numerically less wanted in both pleasantness and wanted intake at 10 and 20 minutes after MD than after CG on their second experimental days but the reverse was true on the first day (in amounts wanted as well as in pleasantness). This difference in effect between Day 1 and Day 2 was reliable and its interaction with MD *vs* CG highly so, but there was no main effect of MD *vs*. CG for this savoury snack.

There was highly reliable variation among the participants in all of the measures. Hence the procedure may well be appropriate for testing variations in the strength of this satiety signal among individuals.

Constructs of appetites for food or water* versus *visceral discomfort

Test-retest reliability of items. There was indirect evidence of moderate to excellent consistency between repeated tests in the relativities among individual participants for each of the ratings for sensed states or food-specific appetites (Table 1). As to be expected for states that are liable to change within several minutes, median test-retest correlations were often numerically higher within sessions (10, 20 minutes) than between sessions (days 1, 2). The exceptions among the conscious self-states were "comfortable" and "contented / happy"; both of these could be used to refer to mood rather than to a sensation.

Table 1 about here

With test and retest on separate days, self-state ratings were better correlated in the control condition (mean $r = 0.60$) than after MD (0.33), possibly reflecting unexpected and/or rapidly changing effects of the MD: at 10 minutes $t(13) = 2.00$, $p < 0.07$; at 20 minutes $t(13) = 4.06$, $p < 0.002$. These correlations were also numerically higher at 20 minutes than at 10 minutes, reliably so in the control condition, $t(13) = 3.20$, $p < 0.007$. This indicates greater stability in sensed visceral state after sufficient time since the ending of the meal.

Correlations between ratings of the pleasantness of a named food did not differ between day-to-day tests and the 10-minute interval, except for being slightly higher for the short interval with the chocolate-coated sugar confection (the UK version of the Mars Bar brand; Table 1). Wished amounts of each food varied in correlating slightly better or worse at the brief test-retest interval, although Mars Bar showed a marked decrease. The relatively high pleasantness ratings for Mars Bar are notable in this connection (mean score, Table 1).

For both pleasantness and amount, the numerical differences in strength of correlation between conditions and between delays were mostly in the same direction as for sensed states but not large enough on average to reach $p < 0.05$.

These test-retest correlations could measure reliability directly if individuals kept the same relative ratings. Such consistency in individual differences should raise the correlation. Hence the largest of the four correlations for each interval in each experimental condition was examined (columns headed Maximum in Table 1). The states having the highest maxima (all $r > 0.87$ for the 10-20 minutes interval) were all aversive: nausea, sluggishness, discomfort, emptiness, flatulence, heaviness and heartburn. Nausea, flatulence and heartburn were equally high in the maxima for day-to-day correlations. Such high r values could arise from the symptom being either present or absent in an individually consistent manner, even between sessions. In contrast, ratings of "heavy / fat" were not at all correlated between days, possibly because feeling "fat" is liable to reflect variations in self-esteem rather than in visceral state.

For states relating to motivation to eat or drink, however, the maximum correlation was not greater within sessions than between sessions: see full, satisfied, bloated, comfortable, contented and thirsty in Table 1. Thus that indication of a consciously sensed state for the adverse visceral symptoms was not shared by the food-specific appetites.

Since the individual items appeared to be moderately to highly reliable, associations between items could be considered.

Nicely full. In each of the eight sets of data, one of the two factors accounting for most variance had high and nearly equal loadings for "full" (median 0.90) and "satisfied / finished" (0.86). This finding demonstrated the fallacy in assuming that ratings of how "full" one is measures a sensation of fullness of the stomach, rather than an expression of satisfaction with the amount already eaten (Booth, 1976), i.e. inhibition of the disposition to eat by effects of exercising that appetite for food -- the motivational state of some depth of satiety.

Hunger versus *thirst*. Motivations to eat and to drink were clearly separated by these quantitative judgments of self-state shortly after consuming soup. Ratings of thirst always had their highest loading (median 0.87, quartiles 0.65, 0.89) on a different factor from factors most highly loaded by ratings of "empty" and/or (negative loadings of) "satisfied" and "full." Usually another item had its highest loading on the same factor as thirst but this varied among the aversive states and also warmth. The appetite for a meal and its sating can therefore be differentiated between appetite for foods (hunger) and appetite for drinks (thirst) and their satieties, at least with some menus.

Overfullness versus *other discomfort*. The evidence for associatively aversive effects of concentrated maltodextrin from the conditioning of satiety measured on subsequent days (Booth & Davis, 1973; Booth *et al*., 1982; Booth, 2009a) does not distinguish an overstimulation of systems mediating normal satiety from discomfort arising from other effects of MD. A parallel question about the motivationally aversive effect that suppresses eating at the time of digestion can be addressed from the present data: is this entirely an excess of satiety (oversatiation, perhaps 'bloating') or does it extend to appetite-suppressant nausea and/or abdominal discomfort of some sort?

The early effect of MD on its first day is particularly relevant, both because of generalisation from experience in life and for our design of a single-session test for effective visceral signaling. The two biggest multivariates in PCA (rotating components with Eigenvalue > 1) of self-state ratings at this 10-minute delay were a factor accounting for 25% of the variance on which (lack of) Emptiness loaded -0.82, with slightly to substantially smaller contributions from Satisfied (0.77), Full (0.72) and Comfortable (0.69), and a lack of Gas (-0.67) and of Heartburn (-0.66), and a factor (24% of variance) loaded most heavily by Nausea (0.92) and Sluggishness (0.90). These two factors were conceptually distinct from two smaller singleton components, Thirst (0.84; 19%) and Bloat (0.91; 11%). Early on CG's first day, however, Bloat (loading 0.93) combined with Discomfort (0.93) and Gas (0.91) in the biggest component (35% of variance), while "nicely full" (Full 0.97; Satisfied 0.94) was a distinct factor of its own, next (25%). This contrast in patterns between the control and experimental conditions on the first day opens the possibility that some reconstruction of the normal sense of visceral sating was provoked by the earliest aversive effects of concentrated MD.

By the second day on MD, the construct of satiety had become more distinct. Full (0.92) and Satisfied (0.90) with Warmth (0.77) were alone on a component accounting for 23% of the variance, and separate from Comfortable (0.77), Empty (0.77) and without Bloat (-0.68) on the smallest component (13%).

At 20 minutes after the start of ingestion, the effects of MD were clearly structured, even on Day 1. Not being Empty (-0.87), Full (0.74) and Satisfied (0.65) were the only terms loading heavily on a component accounting for 18% of the variance. Warmth (0.91) was separate, by itself on 13%. The adverse symptoms were divided among other components, with Thirsty (0.71) joining the largest component (25% of the variance) comprised of

Heartburn (0.94), Nausea (0.88) and Sluggishness (0.82). Bloat (0.86) and Discomfort (0.82) were by themselves on 14%.

Similar (although not completely consistent) distributions of adverse effects over factors in the other experimental conditions indicated that an uncomfortable sensation of distension was distinguishable from nausea and from symptoms of indigestion, as well as each being separate from normal satiety.

Thirst was usually associated with one or more other states but these were not always aversive, as at 20 minutes after MD. Sometimes 'thirsty' loaded on a factor in which the other main term was 'warmth.' That is, there was no indication of this sort that thirst itself at these levels was unpleasant.

Effects of concentrated maltodextrin on the normal and adverse self-states

Evidence on contrasts in self-states between the MD and CG conditions was limited by the low power of the experiment. Furthermore there were highly reliable subject effects in most measures and so individualised analyses are needed (e.g. Booth, Sharpe, Chechlacz *et al*., submitted; Chechlacz *et al*., 2009) but there is not space here for the details of personal affect. The best reliabilities of group mean differences between MD and CG were $P < 0.06$ for nausea and $P < 0.2$ for bloat. Nevertheless, specific differences in group mean values are worth considering for further investigation. All self-state ratings were in the same format and so are directly comparable numerically.

For nausea (feeling sick), bloat and the PCA factor represented by an average of discomfort, gas (flatulence) and heartburn, the greatest increase after MD over CG was at 20 minutes on Day 2. This may indicate the emergence of a stereotype of adverse effects at 20 minutes after the start on one flavour of soup.

Effects of MD on rated states called "hunger" did not reach a reliable size in this group of 14 eaters. This illustrates once again the greater robustness of rated wanting ("how pleasant it would be to eat right now") of named foods (Booth *et al*., 1982), reported above. The numerical differences between MD and CG conditions on both days were greater at 10 minutes than 20 minutes for "full" and greater at 20 minutes for rating oneself as "satisfied / finished" relative to usual. However, a larger group and/or thorough examination of individuals' data would be needed to ascertain if this is a temporal difference between sensation-based responding and a more broadly based satiated response. The same options of stereotype development or different mechanisms remain for this normal satiety as for thirst and adverse states.

The largest numerical difference in ratings between MD and CG was observed for "thirst" relative to usual at 10 minutes after the start of ingestion on Day 1, when the participants had had least experience of this experimental paradigm (Figure 2). Thirst was the only state to correlate reliably with the average pleasantness of the four named sweet foods, r = - 0.62, $p < 0.02$. That is, there was reliable inhibition of hunger motivation, at least for these four foods, associated with the effects of MD that were expressed in the term for wanting a drink. On this evidence, an osmotic effect of digested MD may suppress appetite for food by generating a drinking-facilitatory signal of dehydration. An emerging construct of adverse effects (see above) might have diverted attention from what was originally recognised specifically as thirst. Alternatively, thirst might have developed earlier and very briefly, while the various sorts of visceral discomfort developed later from different or more extreme physiological effects of concentrated MD.

Figure 2 about here

Associative effect of cMD on intake

A prerequisite for the conditioning of satiety by effects of concentrated MD is that its immediate satiating effect is not operative within the training meals (Booth *et al*., 1976). Hence the meal was designed to be short enough to minimise reduction of intake before conditioning. The present design succeeded in limiting the mean reduction in intake of yogurt by MD to 1.3 g on the first days with MD and CG, and 0.3 g on the second days (main effect $p > 0.5$) with grand mean of intake being 283.0 g.

The differential conditioning of satiety by two days each on MD or CG with its own flavour of yogurt was tested by changes between a preliminary day and a follow-up day in the intakes of the differently flavoured yoghurts, each eaten freely after a fixed portion of a mixture of equal volumes of MD soup and CG soup. A mean of 15.7 g less of the meal with yogurt flavour paired with MD was eaten on the final day than on the preliminary day, whereas a mean of 0.6 g more was eaten afterward of the meal including the CG-paired flavour of dessert, $F (1,11) = 2.15$, $\eta^2 = 0.16$, $p < 0.18$, power = 0.27. Although not statistically significant, this numerical difference of differences is in the direction predicted for the conditioning of satiety and not of preference, consistently with previous observations of learnt sensory-gastric inhibition of appetite for food (Booth, 2009a).

Discussion

Normal and adverse effects of eating

The results of this experiment confirmed and extended the original finding that the rapidly digested starch derivative, maltodextrin (MD), promptly reduces appetite for food when ingested on an empty stomach (Booth *et al*., 1976, 1982). This process of satiation of hunger was evident from 10 minutes after the start of consumption of MD-containing food. It continued until at least 20 minutes with the 18 g of MD used.

In addition, also as previously observed (Booth *et al*., 1982), the pleasantness of eating an item of food was a more sensitive index of the momentary state of satiety than was the amount of the item wanted for eating. This seems likely to be a mensurational issue rather than a mechanistically substantive one, because the two ratings were well correlated. How pleasing it is to be eating each of a number of foods can be placed straightforwardly on one psychological scale of appetite for food. In contrast, the physical sizes of portions of diverse foods are liable to map onto that hunger scale in proportions that vary among the items -- for example, according to their perceived nutrient contents or previously experienced satiating effects (Dibsdall *et al*., 1996; Oakes & Slotterback, 2001).

The results were also in the direction consistent with earlier evidence for an associatively aversive effect of MD in concentrated form, namely the conditioning of satiety (in human subjects: Booth *et al*., 1976, 1982, 1994; Booth & Toase, 1983; in monkeys: Booth & Grinker, 1993; in rats: Booth, 1977; Booth & Davis 1973; Gibson & Booth, 1986, 2000). However, the key measure of the learnt sating -- a difference of differences in response to the test combination of flavour and gastric cues (Booth, 2009a) -- did not reach reliability. This could have been because the concentration of MD in the training food in this experiment was only about 18% (g per 100 ml), whereas in previous human experiments it was about 25% and in animal experiments 40% or more.

Similarly, there were signs of aversive motivational effects of ingested MD among the diverse constructs of self state that were elicited across the experimental conditions. The strongest indication of a difference from control in symptoms of adverse effects of unusually concentrated MD was high ratings on the item “feeling sick / nauseous,” with “discomfort / bloat” potentially also being intensified. It should be noted that, with the relatively small meal used, these effects of MD brought intensities up from below usual, rather than inducing greater than usual nausea or bloating.

Thirst

The tested concentration of MD produced a reliable reduction in the sating of thirst at 10 minutes after the start of eating on the first day of testing MD, relative to the first day of the control condition. The well established osmoreceptors for thirst are in and around the brain (Bourque, 2008) and do not respond to glucose, even if its levels entering the blood are hypertonic (Fitzsimons, 1971). Hence the observation that MD induced higher than control ratings of thirst was not predicted. Nevertheless, an osmotic effect behind the brush border in the wall of the small intestine could conceivably mediate both the hunger-sating effect of MD and this increase in desire for water. It may be more relevant that the serosal glucose transporter moves sodium ions across the membrane (cf. Dyer *et al*., 2002) and so cMD might raise the tonicity of portal blood to the liver which has neural sensitivities to osmolarity and sodium ions (Kobashi & Adachi, 1993). Visceral osmoreception has been implicated in the dehydration-induced increase in water intake (Stricker, Huang & Sved, 2002), reduction of food intake (Schoorlemmer & Evered, 2002) and hormonal regulation of sodium excretion (Bourque, 2008). Hence afferent activity from somewhere in that system might inform a sense of water deficit sufficiently to facilitate ratings of "thirst" or indeed central activity specific to water in the mouth (de Araujo *et al.*, 2003)

Ratings of thirst do not relate exclusively to water-deficit induced drinking. Cortical areas are activated when people act or talk thirsty who are not involved in deficit-induced drinking (Egan *et al.,* 2003; Farrell *et al*., 2008). It has therefore been suggested that this neural activity reflects conscious thirst, conceived as a bodily sensation that does not depend on signals of water deficit. However, there are several other theoretical possibilities.

Thirst can be conceived as motivation to consume water-yielding materials, whether or not accompanied by any distinctive bodily experience (Booth, 1991). For example, an habitual drink may be desired without any dryness of the mouth or throat or other symptom of need to conserve water or excrete sodium ions such as dizziness or infrequent micturition.

Another scientifically distinct meaning of the complaint "I'm thirsty" or avid consumption of fluid, without invoking a sensation, is the successful recognition of a bodily deficit of water without awareness, or the transmission directly to action of intracellular or extracellular signals of water deficit (Booth, 2008). There might not even be a desire for any particular drink. All that is required is the presence in mind of the concept of lack of a drink.

We are a long way yet from dissociating the idea of taking a drink, the disposition to have a drink, any sensation of thirst and unconscious detection of water deficit. More data than a single rating of thirst are needed for cognitive analysis of what the rater is conscious of or not (Booth & Freeman, 1993). So, as yet, we have no real evidence what the rater of the word “thirsty” is conscious of. Therefore the term ‘rated’ thirst is preferable to that of ‘conscious’ thirst. Correct usage of the word “thirsty” is shown by its association on relevant occasions with some other display of a disposition to drink Verbal data are no less objective, reliable and interpretable than physical data and do not disturb the phenomena being investigated nearly as much as drinking does (Booth, 2009b).

It remains to be seen how aversive, if at all, the rated extent of thirst was after ingestion of MD. What is clear is that the thirsty state was more closely related to the suppression of hunger by MD than was any nausea, discomfort or other adverse reaction picked out by the terms used in this experiment. It should be noted that this observation constitutes some external validation of the use of the term “thirsty” in this context.

Finally, the use of a savoury or salt-containing food (tomato soup) cannot account for greater thirst after concentrated maltodextrin, because both the MD and its control (cellulose gum for texture and glucose for sweetness) were delivered in the same soup. At most the increase in rated thirst was primed by the concept or flavour of a soup. It should also be noted that the effect of MD in this experiment was to reduce a lack of thirst relative to usual after a larger meal, not to induce extra thirst.

Prospects for an individualised test

In analyses of variance, subject effects were highly reliable. In correlational reduction of data, a small number of factors accounted for most of the variance and the between-subjects differences were stable within a day’s test. Therefore the present design seems to be suitable for development into screening of individuals for patency of the cMD-induced visceral signal.

In designing a one-shot test for the strength of this signal, it would seem wise to attempt to accommodate individual differences by keeping a wide profile of ratings, rather than a small number of psychometric scales. The latter would force on the experience a consensus across the culture that could be insensitive and might even be bogus. The twelve explicitly or potentially viscero-sensory items would be appropriate, both ingestive and aversive. Since the item-reliabilities appeared to be higher at 20 than 10 minutes after the start of ingestion, the later time might be better for obtaining these ratings.

Affective neuroscience of eating

These results also have some wider implications for the behavioural neuroscience of ingestion.

Adverse states after meals. There is very little scientific information on the phenomenology of post-prandial states. Research on affective states after binges on food has sought indications of associative effects that could explain the development of overeating (Smyth *et al*., 2007) but such studies have generally assessed generic mood, desire to eat, cravings, sense of control or eating itself, not viscerally attributed sensations or food-specific appetites.

Guss, Kissileff, Booth and Nolan (2000) elicited words used to describe bodily states after consumption of food or drink by asking respondents to imagine such situations, including a large meal. People diagnosed with bulimia nervosa wrote almost five times as many terms as healthy controls. Over 80% of the terms could be assigned to a minimum of five categories by literal and lexical criteria. Those with eating disorder provided words in the categories "ill" and "anxious" more often than controls and less often in the categories "satisfied" and "full" (Kissileff, Guss, Booth & Nolan, 2000). The present experiment used the commonest words in fourteen verbally differentiable sets of words from Guss *et al*. (2000). British idiom was accommodated by adding a term to a few terms, namely "feeling sick" to "nauseous" and "discomfort" to "bloat," for "feeling uncomfortably full." Separate reductions of data from each of the eight conditions of the experiment produced four constructs, two appetitive and two aversive, one major and one minor in each valence. Appetites for food (hunger) and for water (thirst) had more variance accounted for by hunger than by thirst, although that might have been the consequence of including more eating-related terms such as potential labels for sensations generated or reduced by food ("full," "empty"), omitting water-related sensations such as "dry."

Soup thickened with the non-nutritive cellulose gum might have proved a disappointment to those who expected substantial sating of hunger; it might even have induced a feeling of emptiness. Indeed, all the ratings on average in this experiment were less than "usual for this time after lunch." Hence it remains to be seen if the social context as well as the physiological effects of bigger imposed or self-determined lunches are reflected in the psychometric structure in a way that brings out larger effects of the digestion of concentrated maltodextrin, or even a different pattern of ratings. Individual differences in habit should also be taken into account: lunch is sometimes used as a snack rather than a meal (Chamontin, Pretzer & Booth, 2003).

'Wanting' versus *'Liking.'* This experiment on MD-induced states was designed on the premise that rated appetite for food is a unitary psychometric construct, encompassing various verbal expressions of a disposition to eat and of accompanying experiences of epigastric hunger pangs and the absence of abdominal fullness (Booth, 1976, 2009b). This position was supported by the finding in this work that the pleasantness to the assessor of eating a food and the amount of that food that the assessor wanted to eat both loaded highly on the same principal component in each of the experimental conditions tested.

The first publication that used ratings of appetite to measure the sating effect of concentrated maltodextrin showed that intensity ratings referring to sensations typical of hunger, the pleasantness of eating food and the amount wished to eat were all reduced by the physiological action of ingested MD and also by the social construct of a meal's energy content (Table 2 in Booth, Mather & Fuller, 1982). It follows that quantitative judgments of the pleasantness of ingesting a material cannot distinguish sensual pleasure induced by that activity from the motivation to carry it out, contrary to widespread assumptions (e.g., Cabanac, 1971; Laeng, Berridge & Butter, 1994; Finlayson, King & Blundell, 2007; cp. Booth, Higgs *et al*., 2010).

For the same reasons, the concepts of liking or disliking a food are not specific to sensory factors in preference. They function identically to the concepts of the pleasantness or unpleasantness of eating a food in a set of ratings of the strength of appetite (Booth, 1990, 2009b; Knibb *et al*., 2001), contrary to the interpretation by many users of the ordinal categories from extreme liking to extreme dislike introduced by Peryam and Pilgrim (1957).

There is no question that the construct of desire for a goal, even when in physical contact with it/her/him/them, is different from the construct of pleasure obtained from interaction with the goal (Litt, Khan & Shiv, 2010). The issue for investigators is how to ensure that assessors differentiate the constructs in their ratings. Asking a single question about each construct does not do it. Research in behavioral neuroscience needs participants to show the cultural bases of their cognition and affect as well as its physiological bases.

Sweet versus *savoury snackfoods*. Human behavioural neuroscience has to deal with a complex social and technological culture, surrounding the consumption of foods and beverages as well as solely interpersonal activities. Yet the key construct of a snackfood has received to very little cultural analysis. To design our measure of hunger, we served as amateur participant observers in selecting widely popular items that were available in portions of a few mouthfuls at most. The four sweet items operated in a unified way to some extent but some *prima facie* distinctions among them may have been reflected in performance. The biscuit was most effective over the group at showing a sating effect of MD. Yet some of the largest differences in individuals' ratings were seen for banana. Responses to the calorific fruit might be more sensitive in people who are concerned about healthy eating. The Mars Bar was chosen in large amounts and rated very high in pleasantness: possibly the extreme sweetness of this item creates a distinctive pleasure, unlike even a biscuit or doughnut, let alone a banana (Booth, Higgs *et al*., submitted).

It may have been inappropriate to ask people to consider eating a savoury food shortly after a meal that had ended with yogurt (in an unlimited amount), fitting the cultural role of a dessert. Alternatively or as well, the need to prepare cheese and cracker may have made it insufficiently familiar as a snack, unlike the other four items which are more portable and ready to eat after opening the packet or peeling the banana.

*Awareness of associative contingencies in the conditioning of satiety***.** Awareness of the learnt contingency between cue and consequence may be impossible to exclude for all human associative conditioning of behavioural responses (Lovibond & Shanks, 2002). On the other hand, for some types of CS-US contingency the evidence for awareness remains thin -- for example, the conditioning of sensory facilitation or inhibition of eating by postingestional effects of food (Brunstrom, 2004). It is even unclear whether or not learners were aware of the visceral US that conditioned the preference or aversion.

This experiment addressed that issue by exploring the affectively positive and negative effects of an associatively aversive visceral stimulus generated by ingested food. The results put us in a better position to relate the strength of individuals' conditioning of satiety to their awareness of the gastric and sensory cues, of some viscerally referred consequences that may be associatively aversive and of the predictiveness of those consequences from those cues.

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Table 1. Median and maximum product-moment correlation coefficients (r) between ratings of a sensed or appetitive self-state on the first and second days in a condition at a delay and between ratings at 10 and 20 minutes' delay on the same day in a condition (N = 14, r >= 0.50, *p* < 0.05), with the grand means of the ratings.

	r (Day	1, Day 2)	r (10' ,	20')	Mean
Rated term	Median	Maximum	Median	Maximum	score
How weak/strong relative to usual[a]					
FULL	0.25	0.82	0.51	0.74	8.0
SATISFIED / FINISHED	0.29	0.68	0.53	0.67	7.7
BLOATED / SWOLLEN	0.42	0.69	0.48	0.65	4.1
COMFORTABLE	0.75	0.78	0.39	0.70	8.2
SICK FEELING / NAUSEA	0.70	0.98	0.85	0.96	2.3
SLUGGISH / SLEEPY	0.50	0.82	0.85	0.96	3.5
DISCOMFORT / ACHE	0.50	0.68	0.72	0.89	1.9
EMPTY / UNSATISFIED	0.48	0.83	0.79	0.90	4.9
Strength relative to usual now[a]					
CONTENTED / HAPPY	0.70	0.78	0.46	0.77	7.1
FULL OF AIR/GAS / FLATULENT	0.49	0.88	0.72	0.88	1.8
WARMTH	0.47	0.56	0.71	0.82	5.8
HEAVY / FAT	-0.07	0.03	0.49	0.95	3.2
HEARTBURN	0.70	0.94	0.92	0.97	1.3
THIRSTY	0.57	0.97	0.79	0.81	5.6
How much/little I'd eat right now[b]					
A plain 'digestive' biscuit	0.62	0.74	0.57	0.70	1.2
Cheese-spread on cracker	0.52	0.70	0.60	0.82	1.2
A banana	0.74	0.99	0.83	0.96	1.0
A mini Mars Bar	0.53	0.64	0.11	0.72	1.5
A doughnut	0.62	0.96	0.45	0.60	0.7
How pleasant a mouthful would be[c]					
A plain 'digestive' biscuit	0.83	0.84	0.83	0.87	1.8
Cheese-spread on cracker	0.68	0.76	0.68	0.77	2.5
A banana	0.76	0.84	0.77	0.83	1.9
A mini Mars Bar	0.51	0.59	0.62	0.90	4.2
A doughnut	0.33	0.58	0.35	0.89	2.2

[a]10 = usual at this time after lunch.
[b]Fraction or multiple of the item by itself that would be eaten right then.
[c]10 = extremely pleasant. -10 = extremely unpleasant.

Captions to Figures

Figure 1. Effects of concentrated maltodextrin at 10 and 20 minutes after the start of its ingestion on rated appetite for (a) four sweet foods (mean score) or (b) biscuits only. CG: control soup with cellulose gum and saccharin. MD: soup containing concentrated maltodextrin.

Figure 2. Rated thirst at 10 and 20 minutes after the start of ingestion on the first day of consumption of either cellulose gum (CG) or concentrated maltodextrin (MD).

Figure 1.

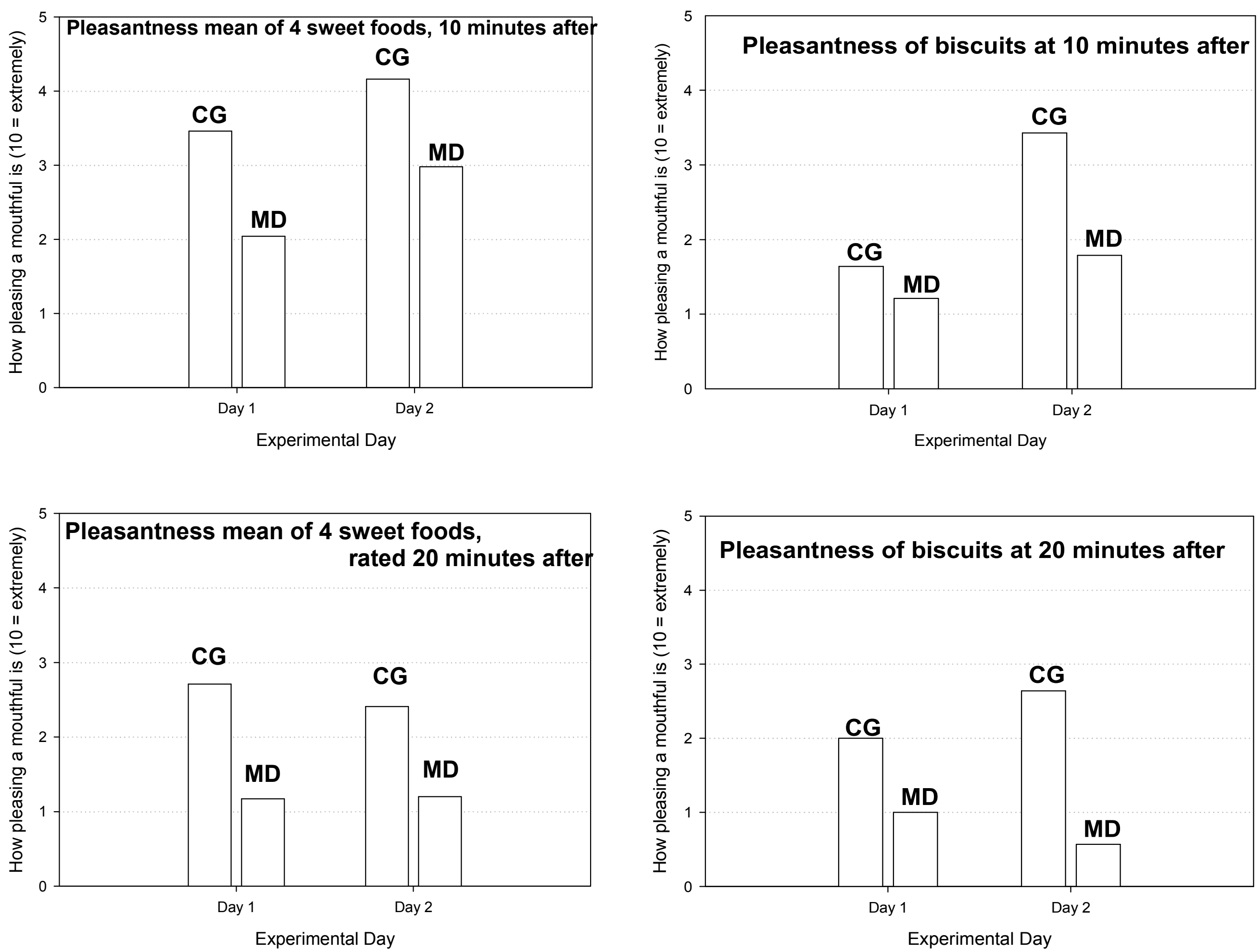
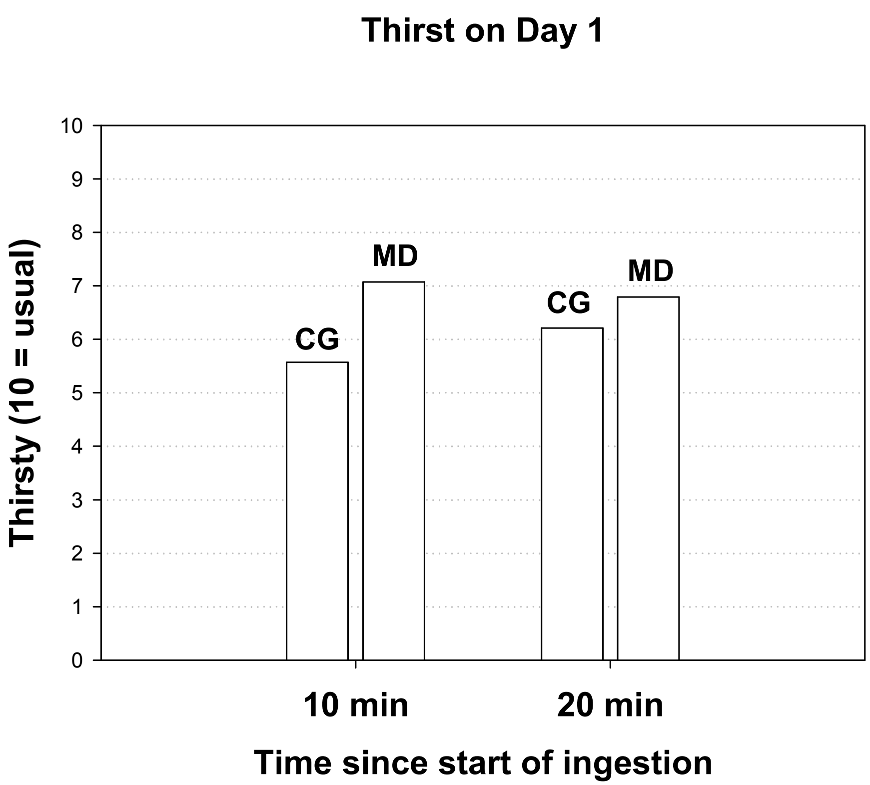

Pleasantness mean of 4 sweet foods, 10 minutes after
How pleasing a mouthful is (10 = extremely)
CG
MD
CG
MD
Day 1
Day 2
Experimental Day
Pleasantness of biscuits at 10 minutes after
How pleasing a mouthful is (10 = extremely)
CG
MD
CG
MD
Day 1
Day 2
Experimental Day
Pleasantness mean of 4 sweet foods,
rated 20 minutes after
How pleasing a mouthful is (10 = extremely)
CG
MD
CG
MD
Day 1
Day 2
Experimental Day
Pleasantness of biscuits at 20 minutes after
How pleasing a mouthful is (10 = extremely)
CG
MD
CG
MD
Day 1
Day 2
Experimental Day

Figure 2


Thirst on Day 1
Thirsty (10 = usual)
10
9
8
7
6
5
4
3
2
1
0
CG
MD
CG
MD
10 min
20 min
Time since start of ingestion