

NO EFFECTS OF SWEET TASTE EXPOSURE AT BREAKFAST FOR 3 WEEKS ON PLEASANTNESS, DESIRE FOR, SWEETNESS OR INTAKE OF OTHER SWEET FOODS: A RANDOMIZED CONTROLLED TRIAL

Katherine M Appleton¹, Jessica Rajska², Sarah M Warwick², Peter J Rogers³

¹Department of Psychology, Faculty of Science and Technology, Bournemouth University, UK

²Faculty of Health and Social Sciences, Bournemouth University, UK

³Nutrition and Behaviour Unit, School of Psychological Science, University of Bristol, Bristol, UK

Address for Correspondence:

Prof. Katherine Appleton, Department of Psychology, Bournemouth University, Poole House, Fern Barrow, Poole, UK; Tel: +44 (0) 1202 965985; Fax: +44 (0) 1202 965314; Email: k.appleton@bournemouth.ac.uk

Word Count: 6341

No. of Tables: 3

No. of Figures: 4

Supplementary Data: Yes

Running Title: Repeated sweet taste exposure at breakfast



This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI

10.1017/S000711452100235X

The British Journal of Nutrition is published by Cambridge University Press on behalf of The Nutrition Society

Abstract

This work investigated the effects of repeated sweet taste exposure at breakfast on perceptions and intakes of other sweet foods, while also examining effects due to duration of exposure (1/3 weeks), test context (breakfast/lunch), and associations between taste perceptions and intakes. Using a randomised controlled parallel-groups design, participants (N=54, 18 male, mean age: 23.9±5.8yrs, mean BMI: 23.6±3.5kg/m²) were randomized to consume either a sweet breakfast (cereal with sucralose) (N=27) or an equicaloric non-sweet breakfast (plain cereal) (N=27) for 3 weeks. On days 0 (baseline), 7, and 21, pleasantness, desire to eat and sweetness were rated for other sweet and non-sweet foods, and sweet food consumption was assessed in an *ad-libitum* meal at breakfast and lunch. Using intention-to-treat analyses, no statistically significant effects of exposure were found at breakfast (largest $F(2,104)=1.84$, $p=0.17$, $\eta_p^2=0.03$), or lunch (largest $F(1,52)=1.22$, $p=0.27$, $\eta_p^2=0.02$), and using Bayesian analyses, the evidence for an absence of effect in all rating measures was strong to very strong (smallest $BF_{01}=297.97$ ($BF_{01error}=2.68\%$)). Associations between ratings of pleasantness, desire to eat and intake were found (smallest $r=0.137$, $p<0.01$). Effects over time regardless of exposure were also found: sugars and percent energy consumed from sweet foods increased throughout the study smallest ($F(2,104)=4.54$, $p=0.01$, $\eta_p^2=0.08$). These findings demonstrate no effects of sweet taste exposure at breakfast for 1 or 3 weeks on pleasantness, desire for, sweetness or intakes of other sweet foods in either the same (breakfast) or in a different (lunch) meal context.

Clinical Trial Registration: clinicaltrials.gov ID: NCT03442829, 21st Feb, 2018.

Keywords: sweet; pleasant; desire; intake; exposure; taste; sugar; sucralose

Abbreviations: % - percent; A – appetite ratings; g – grams; kg – kilograms; kJ – kilojoules; kcal – kilocalories; m – metres; mJ – megajoules; mm – millimetres; SD – standard deviation; TMI – Test Meal Intake; TT – Taste test; VAS – visual analogue scales.

INTRODUCTION

The World Health Organization (WHO) currently recommends ‘*In both adults and children, the intake of free sugars should be reduced to less than 10% of total energy intake*’⁽¹⁾, and ‘*A reduction to less than 5% of total energy intake would provide additional health benefits*’⁽¹⁾.

These recommendations are based on associations between sugar consumption and increased risk of dental caries, Type II diabetes and cardiovascular disease, and on associations between energy intake, overweight and obesity⁽¹⁾.

In order to facilitate this reduced sugar consumption, the WHO and various public health agencies currently recommend reducing our consumption of *sweet taste*, regardless of the source of the sweet taste, i.e. regardless of whether the sweet taste stems from sugars, low-calorie sweeteners or other sweet tasting food items such as fruit^(2,3). The rationale here is that reducing exposure to sweet taste will reduce preferences for sweetness and thus reduce the consumption of other sweet-tasting foods and beverages, including sugar.

There is however very little empirical evidence to support a relationship between repeated sweet taste exposure (regardless of source) and subsequent preferences or intakes of other sweet foods. A recent systematic review of the published literature⁽⁴⁾ found no clear consistent effects in cohort studies (N=7) or long term interventions (N=5). Some evidence for an *inverse* relationship between repeated sweet taste exposure and preferences for other sweet foods was found in short term intervention studies (N=9), but no effects were found on sweet food intakes⁽⁴⁾. An inverse relationship between sweet taste exposure and subsequent preferences was found in two short-term studies in several measures^(5,6), although no effects were found in four other studies⁽⁷⁻¹⁰⁾, and one study found increased demands for other sweet foods following increased exposure⁽⁹⁾. Since the systematic review was undertaken, Fantino et al.⁽¹¹⁾ also report no effects of 5-weeks exposure to low-calorie sweetened beverages compared to water on sweet food intakes, Carroll et al.⁽¹²⁾ report no effects of 3-weeks exposure to sweet versus plain breakfasts on subsequent sweet food preferences or intakes, and we recently reported no effects of sweet taste exposure from four portions of a low-calorie sweetened beverage compared to water on sweet food intakes⁽¹³⁾.

Effects are inconsistent, and the evidence investigating the impacts of sweet taste exposure on subsequent preferences or intakes of other sweet foods is limited. Few studies are available, the majority of studies did not investigate effects of sweet taste exposure as a primary research aim, and not all studies report necessary measures or appropriate data to address this research question (e.g. sweet food intake is not separated in all studies from non-sweet food intake). Preferences and intakes are also often considered synonymous, yet preferences and intakes can be unrelated during everyday consumption⁽¹⁴⁻¹⁷⁾, where intake can be highly varied, while preferences tend to be more constant^(15,17).

This study was conducted to contribute directly to the evidence base investigating the effects of a repeated exposure to sweet taste. Our primary aim was to investigate the effects of sweet taste exposure on subsequent perceptions and intakes of other sweet foods, using a short-term intervention study. Secondary aims further investigated effects as a result of duration of exposure (1 week, 3 weeks) and test context (breakfast, lunch), and associations between the perceived pleasantness, desire for, sweetness, and intake of sweet-tasting foods. Note: throughout this work, sweet taste refers solely to the *taste* of a food item (sweet vs non-sweet); this does not necessarily reflect its sugar content.

METHODS

Design

A randomised controlled parallel-groups trial was undertaken, in which participants were randomized to consume either a sweet breakfast or a non-sweet breakfast for 3 weeks. Ratings and intakes of other sweet and non-sweet foods were assessed at breakfast and at lunch on day 0 (baseline), day 7, and day 21.

Participants

Fifty-four adults (18 male, 36 female, with a mean age of 23.9 ± 5.8 years and a mean BMI of 23.6 ± 3.5 kg/m²) took part. Participants were required to regularly consume breakfast, to be non-smokers, not dieting, and to have no known taste or appetite disorders, to have no known food allergies, and to be able to visit Bournemouth University, UK and undertake all measures on six scheduled occasions. Fifty participants were required (25 per group), to detect a difference

between groups in change in pleasantness from day 0 to day 21, of 15/100 mm with a standard deviation of 19/100 mm, at a power of 0.8, assuming an alpha of 0.05⁽¹⁸⁾. This effect size was calculated based on the pleasantness ratings reported in response to sweet taste exposure in the comparable short-term intervention studies of Hetherington and colleagues^(6,19), where changes in pleasantness ratings over 15 – 22 days of sweet taste exposure ranged between 8.6 – 19.6 mm with standard deviations of 16.2 – 27.7 mm, and assumes no change in pleasantness ratings in response to the non-sweet taste exposure, as was also demonstrated in these studies^(6,19).

Participants were recruited from Bournemouth University and the surrounding area, and enrolled by researchers for a ‘Study investigating sweet food consumption, choices and preferences’. Participants were not informed about the study purpose, but the specification of sweet food consumption in the study title was intended to facilitate the recruitment of participants who would like and be willing to consume all study foods, and to adhere to all study procedures.

The study was given ethical approval by the Research Ethics Committee of Bournemouth University, UK, prior to commencement and was registered as a clinical trial on clinical trials.gov (ID: NCT03442829) on 21st Feb, 2018. The study was run in accordance with the Declaration of Helsinki and the ethical guidelines of the British Psychological Society. All participants provided written informed consent in advance of their participation. The trial was run as detailed in the registration, although data were also analysed using alternative methods as described in the analysis section.

Participants were randomized to intervention arms by block randomization using an allocation ratio of 1:1 (block size=8 participants), using a random number generator, by a researcher with no contact with participants. Randomization was stratified by self-reported habitual consumption of a sweet or a non-sweet breakfast, as some effects of habitual consumption have previously been found in exposure studies^(20,21), and differences in appetite have been found based on habitual breakfast versus no breakfast consumption^(22,23).

Intervention / Control

Participants were randomized to two study arms: sweet taste exposure or no sweet taste exposure. Exposure was undertaken at breakfast using the whole breakfast meal, thus

participants either consumed an entirely sweet breakfast or an entirely non-sweet breakfast for the duration of the study. Breakfast was chosen for the exposure manipulation as a meal that is commonly consumed in the UK in both entirely sweet and entirely non-sweet forms. To deliver the manipulation, participants were provided with a packet of a typical UK non-sweet boxed breakfast cereal (*Cornflakes, Sainsbury's Supermarkets Ltd., London, UK*) per week, for consumption at home, which contained either a bag of sucralose or no sucralose. This breakfast cereal is commonly available in sweet and non-sweet versions in the UK, and also represents a plain breakfast cereal compared to those with additional tastes, such as fruit, nuts or chocolate. Sucralose (*Granulated Sweetener, Asda, Leeds, UK, 18 kJ/g*), a low-calorie sweetener approved for use in foods and beverages globally⁽²⁴⁾ was used to provide a sweet taste without significant additional energy. Participants were instructed to consume the cereal every day, for breakfast, and in the event that they also received a bag of sweetener were asked to add two teaspoons of the provided sweetener (2 x 3 g sweetener, providing 2 x 0.5 g sucralose) to each bowl of cereal (equivalent in taste to 2 teaspoons (2 x 5 g) of sucrose), and one teaspoon of sweetener (3 g sweetener, 0.5 g sucralose) to any drinks consumed at the time. Participants who did not receive sweetener were asked to avoid adding anything to their cereal (except for milk), and to avoid other sweetened foods and beverages during breakfast. In the event that a participant was unwilling to add sweetener to a habitual breakfast drink, they were asked instead to consume the drink throughout the meal, to maintain a sweet taste experience overall, while enhancing compliance with other study procedures. Our intention was that participants experienced either an entirely sweet breakfast or an entirely non-sweet breakfast for the exposure period. The non-sweet breakfast furthermore, was simply not sweet, as opposed to savoury or salty. Adherence to all instructions was checked verbally at each subsequent test day.

Packets of cereal were created by a researcher with no contact with participants and provided sealed, thus all researchers in direct contact with participants were blinded to intervention allocation. Participants were not blinded to taste condition, but were blind to other study conditions and were not told the specific sweetener (sugar or low-calorie sweetener) used. Exposure was undertaken for 3 weeks, allowing for outcome assessments on Days 0, 7 and 21.

Outcomes

Our primary outcomes were ratings of pleasantness, desire for and sweetness of other sweet foods, and intakes of other sweet foods, at breakfast. Secondary outcomes were ratings of pleasantness, desire for and sweetness of other sweet foods and intakes of other sweet foods at lunch, and ratings of pleasantness, desire for and sweetness of non-sweet foods at breakfast and lunch.

Pleasantness, desire to eat and sweetness:

For these measures, pleasantness refers to the pleasantness of the taste of the foods, desire to eat represents motivation to consume the food in question, which is partly but not fully determined by liking for the food⁽¹⁵⁾, and sweetness refers to the perceived level (intensity) of sweetness of the foods. These measures were made using a taste test, where participants were required to consume a small sample of each of three sweet foods and three non-sweet foods, as detailed in Table 1. These foods were chosen as foods that consistently differ in taste, were familiar to all participants, represented a variety of textures, and were also served in the buffet meal to assess sweet food intakes. Real foods as opposed to sugared water solutions or similar were used to enhance the validity of the ratings^(20,25). Participants were asked to consume each food in full in a pre-specified order, focus purely on the taste of the food and then rate it immediately after consumption. Participants were then asked to rinse their mouths with water and move to the next pre-specified food. Participants rated the samples using 100 mm visual analogue scales (VAS) of: Pleasantness: *'How PLEASANT does this food taste to you right now?',* anchors *'not at all pleasant', 'extremely pleasant'*; Desire to Eat: *'Now, rate how strong your DESIRE TO EAT more of this food is right now?',* anchors *'not at all strong', 'extremely strong'*, and Sweetness: *'How SWEET does this food taste to you right now?',* anchors *'not at all sweet', 'extremely sweet'*. Data were collected using pen and paper measures, and data for each measure were then combined across all three sweet foods and all three non-sweet foods for analysis.

Intakes:

Sweet and non-sweet food intakes were assessed using a buffet meal composed of a variety of sweet foods and non-sweet foods, as detailed in Table 2. The meal represented a standard UK cold buffet meal that could be acceptable for breakfast or lunch, and where an acceptable meal that was entirely sweet, entirely non-sweet or a mixture of sweet and non-sweet foods could be composed. All foods were familiar to all participants and are commonly consumed in the UK. Importantly, the foods were selected based on taste (sweet vs non-sweet), familiarity and acceptability, not based on their sugar content. Participants were free to consume as little or as much as they wished, and intake was assessed by covertly measuring weight of foods consumed⁽¹⁴⁾. Participants were provided with their own individual tray of all foods, and all foods were covertly weighed as provided by the kitchen and again as returned to the kitchen. Returned food included all that was not consumed by each participant, whether they served the food onto their dining plate or not. Weight of food consumed was then converted into energy consumed and sugars consumed using manufacturers' information. Sweet food intake was measured using: percent weight consumed from sweet foods, percent energy consumed from sweet foods, weight of sugars consumed, and percent energy consumed from sugars. Several measures of sweet food intake were included, because at present there is no consensus on the most clinically relevant measure of sweet food intake⁽¹⁶⁾. Sugar content is commonly used as a measure for sweet food consumption, but this measure can be criticised where foods are sweetened with low-calorie sweeteners, or where non-sweet foods contain 'hidden' sugars, where the sweet taste is masked by other tastes⁽¹⁶⁾.

Outcomes were assessed at breakfast and lunch, on day 0 before the intervention was implemented, after one week of exposure on day 7, and after three weeks of exposure on day 21. Taste tests were consistently undertaken immediately in advance of the buffet meal. This ensured that measures of pleasantness, desire to eat and sweetness were unaffected by any intake immediately prior to the taste tests that may mask, distort or alter the perception of tastes during the taste test⁽²⁶⁾. The taste tests also involved the consumption of stipulated amounts of foods, and this was consistent for all participants and on all test occasions, thus consumption during the taste test would be unlikely to differentially effect consumption during the following ad-libitum test meals⁽¹⁴⁾.

Additional measures:

Gender and age were recorded. BMI was calculated from measures of height and body weight, undertaken by a study researcher. Appetite ratings for hunger, fullness and thirst were also measured prior to each meal. These measures were made using 100 mm VAS of: Hunger: '*How HUNGRY do you feel right now?*', anchors '*not at all hungry*', '*extremely hungry*'; Fullness: '*How FULL does your stomach feel right now?*', anchors '*not at all full*', '*extremely full*'; and Thirst: '*How THIRSTY do you feel right now?*', anchors '*not at all thirsty*', '*extremely thirsty*'.

Procedure

The study was run in the Eating Behaviours Laboratory at Bournemouth University, UK, from Feb. – May, 2018, Feb. – May, 2019, and Feb. – March, 2020. Participants came to the laboratory on six occasions: for breakfast and lunch on Day 0 (baseline), Day 7 and Day 21. On each day, participants were asked to arrive fasted, having consumed no alcohol or undertaken any heavy exercise the day before. On each occasion, participants undertook the taste test and then ate from the ad-libitum test meal. Breakfast test sessions were run between 8:00am and 9:30am on each day, and lunch test sessions were run four hours later. Participants adhered to the same times for both test sessions on each test day. Between test sessions, participants were instructed to consume nothing but water. A timeline for each test day is given in Figure 1. Gender, age, height, body weight, and acceptability of all study foods and study procedures were checked in a screening session prior to the first breakfast test session. The acceptability of all study foods was assessed by asking participants to rate their willingness to consume each study food on a nine-point scale from '*not willing*' (scored 1) to '*extremely willing*' (scored 9), with a cut off of a rating > 4 for every study food for study inclusion. To help conceal the study purpose from participants, this list of study foods was described as 'a list of foods that may be included in the study', and included a number of commonly consumed sweeteners and breakfast cereals, that were then not actually part of the study. As part of the screening measures, participants were also asked '*Do you usually consume a sweet or a non-sweet breakfast?*' This question was asked to allow participants to be randomized based on habitual breakfast consumption, but it was asked in a casual manner to avoid drawing attention to the taste of breakfast. Acceptability of all study procedures was checked following detailed explanation of all study instructions, including the

requirement to consume a specified breakfast, as instructed, for three weeks. At the end of Day 0 and Day 7, participants received a designated box of cereal (with or without sweetener) identified by ID number, to consume from the following day onwards as instructed. At the start of Day 7 and Day 21, participants were queried regarding compliance using the questions '*Have you consumed your breakfast each day as instructed?*' and '*Have you had any difficulties?*', and the amount of cereal remaining in each cereal box was checked to ensure a sufficient amount had been removed. These questions were asked in a casual manner, as stated, to encourage participants to admit if they had failed to adhere to any instruction, and to maintain blinding of the researchers during the study. At the end of Day 21, participants were also queried over the taste of the breakfasts they had consumed using the question '*Would you describe the breakfasts you have consumed as part of the study as sweet or non-sweet?*' and debriefed. This question was asked to verify that all participants perceived the intervention exposure as sweet or non-sweet as intended.

Analysis

First, all data were double-measured and double-entered into spreadsheets by two researchers who were blind to allocated breakfast condition. Data were then checked for normality, normality was confirmed, and baseline data were inspected for meaningful differences between exposure groups in all background characteristics.

Rating data were then analysed using 2 x 3 x 2 x 2 repeated-measures ANOVA for differences between exposure conditions (sweet vs non-sweet) over time (Day 0, 7, 21), for the sweet and the non-sweet foods (sweet vs non-sweet). Considering our interest in *generalized* taste preferences, analyses were conducted for rating data that was combined across all three sweet foods and all three non-sweet foods. Correlations between these combined measures and the measures for each of the individual foods are given in Supplementary Tables 1 and 2. Analyses for the measures from each of the individual foods are also given in Supplementary Results 1 and 2. These analyses should be considered exploratory; we had no hypotheses specific to the individual foods or referring to differences between the foods within the sweet and non-sweet food categories. Intake data were analysed using 2 x 3 x 2 repeated-measures ANOVA for differences between exposure conditions (sweet vs non-sweet) over time (Day 0, 7, 21). Gender

was also included in these analyses, as a variable known to effect food intake^(15,17). Gender was also included in the analyses on rating data for completeness; however, effects of gender on taste perceptions are inconsistent, and no main effects of gender were found in our rating data (largest $F(1,50)=0.62$, $p=0.44$, $\eta_p^2=0.01$). Effects of gender in the rating data should again be considered exploratory. Analyses were undertaken for measures taken at breakfast, and repeated for measures taken at lunch. These analyses were undertaken on an Intention-to-Treat basis, with missing data imputed using models based on gender, age, BMI and baseline data⁽²⁷⁾. Imputation was undertaken in place of the use of last observation carried forward as pre-specified in our trial registration, to allow consideration of the natural variation in perceptions and intakes⁽²⁷⁾. Analyses using last observation carried forward are also provided in Supplementary Results 3. Both sets of analyses revealed comparable effects. Significant effects of time in all analyses were investigated using post-hoc Bonferroni t-tests. Effects sizes (η_p^2) are also reported in the text. Bayes factors demonstrating the evidence supporting the alternative hypothesis (BF_{10}) are also provided where significant effects were found, and Bayes factors demonstrating the evidence supporting the null hypothesis compared to that supporting the alternative hypotheses (BF_{01}) are reported for all exposure x time interactions.

Finally, associations between rating and intake outcomes were investigated using partial correlations across the whole data set. For these correlations, all data were treated equally, regardless of day and breakfast / lunch test context, resulting in the inclusion of 310 data points (54 participants x 6 assessment time points, minus missing data due to drop-out). Participant ID was used as a controlling variable, to account for the use of data from multiple time-points.

ANOVA and correlational analyses were conducted using IBM SPSS (version 23.0). Significance was set at $p<0.01$ to account for multiple testing; significant values from $p=0.01$ to $p=0.05$ were considered as trends to ensure no effects were missed. Bayes factors were computed using JASP (version 0.14.1.0), using the comparison to a null model option and 10,000 posterior samples. Bayes factors can be interpreted in terms of the strength of support provided for a hypothesis. $BF_{01} < 3$ is regarded as weak evidence in support of the null hypothesis, $BF_{01} = 3$ to 10 is regarded as moderate evidence, $BF_{01} = 10$ to 150 is regarded as strong evidence, and $BF_{01} > 150$ is regarded as very strong evidence in support of the null hypothesis. Data are reported as

mean \pm standard deviation in Tables, and as mean \pm standard error in Figures, unless otherwise stated.

RESULTS

Participants

Of the 54 participants recruited, 27 participants were randomised to consume sweet breakfasts and 27 were randomised to consume non-sweet breakfasts. The two groups were comparable in gender, age, BMI, habitual self-reported breakfast type, and baseline (Day 0) ratings of the foods and intakes at breakfast. See Table 3 for all baseline data.

Compliance

The flow of participants through the study is given in Figure 2. All 54 participants completed baseline breakfast and lunch measures, 52 (96%) participants completed breakfast and lunch measures on Day 7 (26 participants in the sweet exposure condition, 26 participants in the non-sweet exposure condition), and 48 (89%) participants completed breakfast and lunch measures on Day 21 (23 participants in the sweet exposure condition, 25 participants in the non-sweet exposure condition). Drop-outs were due to scheduling clashes or were due to illness unrelated to the study. Self-reported compliance with study procedures outside the laboratory was good. All participants reported following all study instructions, no difficulties, and consumption of sweet or non-sweet breakfasts as intended based on group allocation, without harm.

Pleasantness

Breakfast: In pleasantness ratings at breakfast, higher ratings were given for the sweet compared to the non-sweet foods ($F(1,50)=33.99$, $p<0.001$, $\eta_p^2=0.41$; $BF_{10}>1500$ ($BF_{10error}=0.77\%$)). Pleasantness of all foods also tended to decrease over time ($F(2,100)=3.19$, $p=0.05$, $\eta_p^2=0.06$), specifically from day 0 to day 7 ($t(53)=2.78$, $p<0.01$) (see **Figure 3**). This effect was strongest for the non-sweet foods as rated by females ($F(2,100)=3.13$, $p=0.05$, $\eta_p^2=0.06$), from day 0 to day 7 ($t(35)=2.88$, $p=0.01$), and from day 0 to day 21 ($t(35)=2.07$, $p=0.05$). There were no statistically significant exposure x time interactions (largest: $F(2,100)=0.53$, $p=0.59$, $\eta_p^2=0.01$; smallest: $BF_{01}=297.97$ ($BF_{01error}=2.68\%$)).

Lunch: At lunch, higher pleasantness ratings were again found for the sweet compared to the non-sweet foods ($F(1,50)=20.99$, $p<0.001$, $\eta_p^2=0.38$, $BF_{10}>1500$ ($BF_{10error}=1.62\%$)). There were no statistically significant exposure x time interactions (largest $F(2,100)=0.61$, $p=0.55$, $\eta_p^2=0.01$; smallest: $BF_{01}=1275.38$ ($BF_{01error}=6.36\%$)).

Desire to eat

Breakfast: In desire to eat ratings at breakfast, higher ratings were given for the sweet compared to the non-sweet foods ($F(1,50)=20.88$, $p<0.001$, $\eta_p^2=0.30$; $BF_{10}>1500$ ($BF_{10error}=1.24\%$)). There were no statistically significant exposure x time interactions (largest: ($F(2,100)=1.61$, $p=0.21$, $\eta_p^2=0.03$; smallest: $BF_{01}=687.38$ ($BF_{01error}=1.76\%$)).

Lunch: At lunch, higher desire to eat ratings were given for the sweet compared to the non-sweet foods (smallest $F(1,50)=13.22$, $p<0.001$, $\eta_p^2=0.21$; $BF_{10}>1500$ ($BF_{10error}=1.04\%$)). There were no statistically significant exposure x time interactions (largest ($F(2,100)=0.83$, $p=0.44$, $\eta_p^2=0.02$; smallest: $BF_{01}=440.96$ ($BF_{01error}=5.01\%$)).

Sweetness

Breakfast: In sweetness ratings at breakfast, large differences between sweet and non-sweet foods were found ($F(1,50)=259.51$, $p<0.001$, $\eta_p^2=0.84$; $BF_{10}>1500$ ($BF_{10error}=1.24\%$)). Ratings of sweetness for the non-sweet foods were also found to increase specifically in females ($F(1,50)=3.08$, $p=0.05$, $\eta_p^2=0.06$), from day 0 to day 7 ($t(35)=2.50$, $p=0.02$). There were no statistically significant exposure x time interactions (largest: $F(2,100)=1.87$, $p=0.16$, $\eta_p^2=0.04$; smallest: $BF_{01}>1500$ ($BF_{01error}=4.96\%$)).

Lunch: At lunch, large differences in sweetness ratings between sweet and non-sweet foods were found ($F(1,50)=229.91$, $p<0.001$, $\eta_p^2=0.82$; $BF_{10}>1500$ ($BF_{10error}=0.79\%$)). There were no statistically significant exposure x time interactions (largest: $F(2,100)=1.58$, $p=0.21$, $\eta_p^2=0.03$; smallest: $BF_{01}>1500$ ($BF_{01error}=1.62\%$)).

Intakes

In weight of food, energy and sugars consumed, males consumed significantly more than females at breakfast and lunch (smallest: $F(1,52)=7.19$, $p=0.01$, $\eta_p^2=0.12$; smallest: $BF_{10}=5.02$ ($BF_{10error}=1.17\%$)). No further statistically significant effects of gender were found (largest: $F(2,100)=2.76$, $p=0.07$, $\eta_p^2=0.05$).

Breakfast: Percent energy consumed from sweet foods increased at breakfast ($F(2,100)=4.55$, $p=0.01$, $\eta_p^2=0.08$; $BF_{10}=2.78$ ($BF_{10error}=0.92\%$)), and there was a trend for sugars consumed to also increase over the three weeks ($F(2,100)=3.57$, $p=0.03$, $\eta_p^2=0.07$; $BF_{10}=2.92$ ($BF_{10error}=0.77\%$)). Increases occurred from day 0 to day 7 (smallest $t(53)=2.43$, $p=0.02$), and from day 0 to day 21 (smallest $t(53)=2.23$, $p=0.03$) (see Figure 4). No statistically significant exposure x time interactions were found (largest $F(2,100)=2.76$, $p=0.07$, $\eta_p^2=0.05$; smallest: $BF_{01}=0.22$ ($BF_{01error}=1.88\%$)).

Lunch: Percent energy consumed from sweet foods at lunch increased over the three weeks ($F(2,104)=5.38$, $p=0.01$, $\eta_p^2=0.10$; $BF_{10}=2.51$ ($BF_{10error}=0.86\%$)), from day 0 to day 21 ($t(53)=2.68$, $p=0.01$). There were no statistically significant exposure x time interactions (largest $F(2,100)=1.09$, $p=0.34$, $\eta_p^2=0.02$; smallest: $BF_{01}=7.54$ ($BF_{01error}=1.62\%$)).

Hunger

Breakfast: Hunger increased and fullness decreased at breakfast over the three weeks (smallest $F(2,104)=4.44$, $p=0.01$, $\eta_p^2=0.08$; smallest: $BF_{10}=2.80$ ($BF_{10error}=2.04\%$)). No effects were found in thirst ($F(2,104)=2.55$, $p=0.08$, $\eta_p^2=0.05$). No statistically significant effects of exposure x time were found (largest $F(2,104)=1.37$, $p=0.26$, $\eta_p^2=0.03$; smallest: $BF_{01}=1.61$ ($BF_{01error}=2.17\%$)).

Lunch: Hunger and fullness at lunch did not change over the three weeks (largest $F(2,104)=2.44$, $p=0.09$, $\eta_p^2=0.05$). There was a trend for thirst to increase over the three weeks ($F(2,104)=4.08$, $p=0.02$, $\eta_p^2=0.07$). No statistically significant effects of exposure x time were found (largest $F(2,104)=0.57$, $p=0.57$, $\eta_p^2=0.01$; $BF_{01}=8.07$ ($BF_{01error}=4.53\%$)).

Associations between ratings and intake

Hunger was negatively correlated with fullness ($r=-0.610$, $p<0.01$). Neither hunger nor fullness were correlated with energy consumed (largest $r=-0.078$, $p=0.17$), but there was a weak negative correlation between fullness and weight of food consumed ($r=-0.135$, $p=0.02$). Weight of food consumed, energy consumed and sugars consumed were positively correlated (smallest $r=0.654$, $p<0.01$).

Percent weight consumed from sweet foods, percent energy consumed from sweet foods, sugars consumed and percent energy consumed from sugars were positively correlated (smallest $r=0.282$, $p<0.01$), but only sugars consumed were associated with overall weight ($r=0.694$, $p<0.01$) and energy consumed ($r=0.654$, $p<0.01$). Percent measures were not correlated with overall weight or energy consumed (largest $r=-0.105$, $p=0.06$).

Pleasantness, desire to eat and sweetness ratings for all sweet foods were correlated (smallest $r=0.459$, $p<0.01$). Pleasantness, desire to eat and sweetness ratings for all non-sweet foods were correlated (smallest $r=0.231$, $p<0.01$). Pleasantness ratings for sweet and non-sweet foods ($r=0.269$, $p<0.01$), and sweetness ratings for sweet and non-sweet foods were also correlated ($r=0.166$, $p=0.01$).

Pleasantness and desire to eat ratings for all foods in the taste test were correlated with weight of that food subsequently consumed (smallest $r=0.210$, $p<0.01$). Pleasantness and desire to eat ratings for sweet foods were not correlated with total weight or energy consumed (largest $r=0.085$, $p=0.14$), but were correlated with sugars consumed, percent weight consumed from sweet foods, percent energy consumed from sweet foods and percent energy consumed from sugars (smallest $r=0.137$, $p<0.01$). Ratings of pleasantness and desire to eat for the non-sweet foods were positively correlated with total weight and energy consumed (smallest $r=0.132$, $p=0.02$), and were negatively correlated with percent weight consumed from sweet foods, percent energy consumed from sweet foods and percent energy consumed from sugars (smallest $r=-0.218$, $p<0.01$).

DISCUSSION

The primary aim of this study was to add to the limited evidence on the effects of repeated sweet taste exposure on subsequent perceptions and intakes of other sweet foods. We found no statistically significant effects of sweet taste exposure at breakfast for 3 weeks on ratings of pleasantness, desire to eat or sweetness of other sweet foods, or on intakes of other sweet foods. The evidence in support of a lack of effect in all ratings was also strong to very strong, allowing firm conclusions. The strength of the evidence provided by the rating measures is an important finding of this study. These results confirm the findings of previous short-term studies^(7-10,12), and conclusions based on longer time-frames⁽⁴⁾. The evidence for a lack of effect in the intake measures was inconsistent, ranging from weak to very strong. This evidence in the intake measures is likely weakened by the high natural variation in individuals' food intake^(15,17). Studies of larger sample sizes may be of value for determining the effects of sweet taste exposure on sweet food intakes, but our findings do mirror those of other studies with a similar design^(8,9,11,12).

In relation to our secondary aims, we also found no statistically significant effects of sweet taste exposure at breakfast based on duration of exposure (1 week, 3 weeks) or test context (breakfast, lunch), but associations were found between ratings of pleasantness, desire for and intake of sweet-tasting foods. We specifically used foods from the buffet meal for the taste test to investigate these associations, and close associations between taste test ratings and subsequent intake of the specific foods were found. Pleasantness and desire for the sweet foods and all measures of sweet food intake were also correlated with each other, but not with overall weight or energy consumed. Pleasantness and desire for the non-sweet foods were also correlated with pleasantness and desire for the sweet foods, but also with overall weight and energy consumed. These findings may suggest that pleasantness and desire for non-sweet foods are more closely related to eating and appetite in general^(5,28-30); these findings thus suggest some degree of specificity to our sweet food perception measures, and that measures of perceptions of non-sweet foods may add little value to studies on sweet taste.

Effects as a result of study duration were also found. Over the 3 week study period (regardless of exposure group), percent energy consumed from sweet foods and sugars consumed in the test

meals increased, and there was a suggestion that the pleasantness of all foods and specifically the non-sweet foods reduced. Effects of duration most likely result from the repeated experience of the test meals. Various work demonstrates changes in the pleasantness and intake of foods with experience, where liking and intake can increase as a result of increased familiarity, learned safety or learned benefit^(7,10,21,25), or where liking and intake can decrease as a result of monotony, boredom or a form of diminished pleasure from the sensory experience or act of consumption^(20,31-34). Monotony, boredom or similar perceptions with the foods to be consumed may explain the reduced acceptability and selection of the non-sweet foods in this study^(20,33), to also drive the increased selection of sweet foods. It is possible furthermore that this effect of monotony is stronger for non-sweet foods than for sweet foods, and that this effect can occur following a single experience of a taste or food item, as this has been demonstrated in single exposure studies^(28,35,36). A range of other food product attributes, such as familiarity, liking, intensity, complexity and consideration as a staple food may also be important in food monotony, and may explain effects over time^(6,19,20,32,33). Importantly, however, we suggest monotony with the test foods as an explanation for our observations – we were not investigating monotony specifically, and further work is needed to confirm this explanation.

Can we explain also why three earlier short-term intervention studies did find effects of sweet taste exposure? In the study by Ogden et al.⁽⁹⁾, a lower restriction of chocolate coins led to higher demands for other sweet foods (study 1), but a follow-up study conducted to address the methodological limitations of this study (study 2) failed to find similar effects. In the study by Hetherington et al.⁽⁶⁾, ranked preferences for sweet foods declined following 15 days chocolate exposure. Here, the combined measures of sweet foods included the measures for chocolate – the eaten food; thus the extent of effects in other sweet foods (separate from those for chocolate) is consequently unclear. In the study by Griffioen-Roose et al.⁽⁵⁾, reduced preferences for sweet foods were found following 24hrs of a solely sweet diet (with the exception of tea and coffee). These effects may again have been found due to a satiety or monotony with sweet taste. The solely sweet manipulation by Griffioen-Roose et al.⁽⁵⁾, however, clearly differs from our manipulation which was undertaken only at breakfast, and from manipulations which focus on specific food products^(7,9,10) and/or are rendered impure by the simultaneous consumption of other sweet tasting food items⁽⁸⁾. It is important to note, that because our manipulation was

undertaken solely at breakfast, participants likely consumed sweet foods over the rest of each day, and we have no measures of this intake. It is possible, therefore, that this sweet food intake was adjusted to counteract any manipulation at breakfast. Investigation of the effects of a longer exposure to a solely sweet diet, or a longer exposure to a more-than-usual sweet diet, would clearly be of value.

The possible influences of test context, test stimuli and test manipulation may suggest important criteria for the demonstration of taste associations in the laboratory^(7,20,25). Additional effects may also be suggested as a result of interactions with texture, temperature and other product attributes, various characteristics of the consumer, and so on^(10,20,21,25,26,31,33). These differences may contribute to the inconsistencies between study findings on sweet taste exposure. However, if very specific criteria are required to demonstrate effects in carefully-controlled laboratory settings, there are clear questions over the generalisability of findings to the real world. The findings of an increasing number of studies now demonstrate no effects of sweet taste exposure on subsequent desires for and intakes of other sweet foods. The value of recommendations to reduce sweet taste exposure in order to facilitate reduced intakes of other sweet foods, including sugars can clearly be questioned. Further evidence would strengthen the evidence base, but a revision of the recommendations may soon be required.

This study may be limited by the specific measures used, as detailed above. Alongside these, our manipulation was undertaken using sucralose, and our effects or lack of effects may have resulted specifically from our use of sucralose. Sucralose is a low-calorie sweetener, which is perceived as highly sweet, and in our study provided a sweet taste while also providing little additional energy, to result in the consumption of breakfasts that were reported as sweet. Some work suggests differing or reduced impacts of sucralose compared to sucrose on taste pathways^(e.g. 37-39). However, in these studies, effects of sucralose are still reported, and the sucralose in our study was not compared to sucrose, but to non-sweet tastants. A more detailed question on the sweetness of the breakfasts, or repeated reporting on each day of breakfast consumption, may have revealed additional insights. Some evidence, furthermore, also suggests differing effects of different low-calorie sweeteners on taste quality and taste mechanisms, thus use of a different low-calorie sweetener may have resulted in differing results⁽³⁸⁾. We also relied

on participants to undertake the exposure period as instructed in their own homes. While all participants reported good compliance and consumption of breakfasts that tasted sweet or not sweet as intended, we have no other evidence that this was the case. Participants may also have varied in liking for their allocated breakfast but, based on our screening measures and study design, we have no reason to believe this would have systematically differed between exposure groups. Furthermore, based on our choice of a plain breakfast cereal and our compliance checks we have no reason to believe that either breakfast was aversive to any participant. Effects related to liking / disliking of the allocated breakfast however may have occurred. There may also have been some impact on our findings of participant awareness of their consumption of a sweet or non-sweet breakfast. Participants could not be blinded to the taste exposure, and various evidence suggests that participant beliefs can effect study outcomes⁽⁴⁰⁾. We aimed to minimize any impact of beliefs by withholding the study purpose from participants and ensuring participants were unaware of all exposure conditions, and anecdotal comments during the debrief session suggested that none of the participants held any beliefs about the study that may have influenced our results. Indeed, the majority of participants assumed that the study was almost entirely observational, where the question on habitual breakfast consumption had been asked during screening to ensure that a habitual breakfast was subsequently provided or was specifically not provided. Participants thus, assumed the study was more about habit than sweet taste. Furthermore, if beliefs were important, the popular belief that sweet taste exposure may increase sweet taste preferences⁽⁴⁾ would likely have resulted in the demonstration of effects of exposure, while we did not demonstrate these effects. Finally, despite reaching sufficient numbers for our *a-priori* power calculations, our study is relatively small in size. Using Bayesian analyses, the evidence provided by all of our rating measures (pleasantness, desire to eat and sweetness) was strong to very strong, but the evidence for a lack of effect in the intake measures was inconsistent, ranging from weak to very strong.

In conclusion, we found no statistically significant effects of sweet taste exposure at breakfast for 3 weeks, compared to no exposure, on the subsequent pleasantness, desire for, sweetness or intake of other sweet foods, and the evidence for an absence of effect was strong to very strong for the pleasantness, desire for and sweetness measures. Our findings confirm those of other short term intervention studies. We also found no statistically significant effects of one versus

three weeks of sweet taste exposure, or dependent on the breakfast or lunch test-meal context. We did, however, find significant associations between our pleasantness, desire for and intake measures, and we found significant changes in sweet food intakes over the course of the study regardless of exposure group, most plausibly due to monotony with the foods used in the test meal. Our findings, taken together with the results of other similar short-term intervention studies, suggest no effects of repeated sweet taste exposure on the pleasantness, desire for, sweetness or intake of other sweet foods.

Acknowledgements

Grateful thanks are extended to Kirsty Probert and Alejandra Torres Sanchez, Faculty of Health and Social Sciences, Bournemouth University, for help with data collection, and to all participants who took part.

Sources of Support

This work was funded by Bournemouth University, UK.

Declaration of Interests

In connection with research on sweet taste, KMA has received funding for research from Unilever R&D Vlaardingen, NL and ILSI-North America; has current funding from TIFN, NL (in collaboration with Arla Foods, DK, American Beverage Association, US, Cargill, US, Dutch Knowledge Centre for Sugar, NL, Firmenich, CH, International Sweeteners Association, BE, SinoSweet, China, Unilever, NL); and from the International Sweeteners Association; and has received speaker's expenses from the International Sweeteners Association, PepsiCo and ILSI-North America. PJR has received funding for research from Sugar Nutrition UK; provided consultancy services for Coca-Cola Great Britain; received speaker's fees from the International Sweeteners Association, the Global Stevia Research Institute, ILSI-Brasil, ILSI-Europe and ILSI-India; and received honoraria from ILSI-Europe. JR, SMW: no conflicts of interest.

Author Contributions

KMA and PJR conceptualized and designed the study; KMA, JR and PJR contributed to methodology; JR, SMW and KMA conducted the research; KMA undertook the analyses; and wrote the initial draft of the paper; all authors reviewed and edited the initial drafts. All authors read and approved the final manuscript.

References

1. World Health Organization. Website: <https://www.who.int/en/news-room/fact-sheets/detail/healthy-diet>. 2014. Accessed 07.08.19.
2. World Health Organization Regional Office for the Eastern Mediterranean. Website: <http://www.emro.who.int/nutrition/strategy/policy-statement-and-recommended-actions-for-lowering-sugarintake-and-reducing-prevalence-of-type-2-diabetes-and-obesity-inthe-eastern-mediterranean-region.html> 2016. Accessed 13.04.17.
3. Pan American Health Organization. Pan American Health Organization Nutrient Profile Model. Washington (DC): Pan American Health Organization; 2016.
4. Appleton KM, Tuorila H, Bertenshaw EJ, de Graaf C, Mela DJ. Sweet taste exposure and the subsequent acceptance and preference for sweet taste in the diet: systematic review of the published literature. *Am J Clin Nutr* 2018, 107, 405–419.
5. Griffioen-Roose S, Hogenkamp PS, Mars M, Finlayson G, de Graaf C. Taste of a 24-h diet and its effect on subsequent food preferences and satiety. *Appetite* 2012, 59, 1–8.
6. Hetherington MM, Bell A, Rolls BJ. Effects of repeat consumption on pleasantness, preference and intake. *Br Food J* 2000, 102, 507-21.
7. Liem DG, de Graaf C. Sweet and sour preferences in young children and adults: role of repeated exposure. *Physiol Behav* 2004, 83, 421-29.
8. Mattes R. Effects of aspartame and sucrose on hunger and energy intake in humans. *Physiol Behav* 1990, 47, 1037-44.
9. Ogden J, Cordey P, Cutler L, Thomas H. Parental restriction and children's diets. The chocolate coin and Easter egg experiments. *Appetite* 2013, 61, 36–44.

10. Sullivan SA, Birch LL. Pass the sugar, pass the salt: Experience dictates preference. *Dev Psychol*
11. Fantino M, Fantino A, Matray M, Mistretta F. Beverages containing low energy sweeteners do not differ from water in their effects on appetite, energy intake and food choices in healthy, non-obese French adults. *Appetite* 2018, 125, 557-565.
12. Carroll HA, Chen Y-C, Templeman IS, Wharton P, Reeves S, Trim WV, Chowdhury EA, Brunstrom JM, Rogers PJ, Thompson D, et al. Effect of plain versus sugar-sweetened breakfast on energy balance and metabolic health: A randomized controlled trial. *Obesity* 2020, 28, 740-48.
13. Appleton KM. Repeated exposure to and subsequent consumption of sweet taste: Reanalysis of test meal intake data following the repeated consumption of sweet vs non-sweet beverages. *Physiology & Behavior*, 2021, 229, 113221.
14. Flint A, Raben A, Blundell JE, Astrup A. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *Int J Obes Relat Metab Disord* 2000; 24: 38-48.
15. Rogers PJ, Hardman CA. Food reward. What it is and how to measure it. *Appetite* 2015, 90, 1–15.
16. Trumbo PR, Appleton KM, de Graaf K, Hayes JE, Baer DJ, Beauchamp GK, Dwyer JT, Fernstrom JD, Klurfeld DM, Mattes RD, Wise PM. Perspective: Measuring Sweetness in Foods, Beverages, and Diets: Toward Understanding the Role of Sweetness in Health. *Adv Nutr* 2021; 12: 343–354.
17. van Langeveld AWB, Teo PS, de Vries JHM, Feskens EJM, de Graaf C, Mars M. Dietary taste patterns by sex and weight status in the Netherlands. *Br J Nutr* 2018; 119: 1195–1206.

18. Howell DC. *Statistical Methods for Psychology* (4th edn). London: Duxbury Press. 1997.
19. Hetherington MM, Pirie LM, Nabb S. Stimulus satiation: effects of repeated exposure to foods on pleasantness and intake. *Appetite* 2002, 38, 19-28.
20. Hoek AC, Elzerman JE, Hageman R, Kok FJ, Luning PA, de Graaf C. Are meat substitutes liked better over time? A repeated in-home use test with meat substitutes or meat in meals. *Food Qual Pref* 2013, 28, 253–263.
21. Song R-R, Chung S-J, Cho SA, Shin HW, Harmayani E. Learning to know what you like: A case study of repeated exposure to ethnic flavors. *Food Qual Pref* 2019, 71, 452–462.
22. Alwattar A, Thyfault J, Leidy H. The effect of breakfast type and frequency of consumption on glycemic response in overweight/obese late adolescent girls. *Eur J Clin Nutr* 2015, 69, 885–890.
23. Thomas EA, Higgins J, Bessesen DH, McNair B, Cornier M-A. Usual breakfast eating habits affect the response to breakfast skipping in overweight women. *Obesity* 2015, 23, 750-59.
24. Magnuson BA, Roberts A, Nestmann ER. Critical review of the current literature on the safety of sucralose. *Food Chem Toxicol* 2017, 106(Pt A), 324-355.
25. Kremer S, Shimojo R, Holthuysen N, Koster EP, Mojet J. Consumer acceptance of salt-reduced “soy sauce” bread over repeated in home consumption. *Food Qual Pref* 2013, 28, 484–491.
26. Li B, Hayes JE, Ziegler GR. Interpreting consumer preferences: Psychohedonic and psychohedonic models yield different information in a coffee-flavored dairy beverage. *Food Qual Pref* 2014; 36: 27-32.

27. Li P, Stuart E. Best (but oft-forgotten) practices: missing data methods in randomized controlled nutrition trials. *Am J Clin Nutr* 2019; 109: 504-508.
28. Appleton KM, Rogers PJ, Blundell JE. Effects of a sweet and a nonsweet lunch on short-term appetite: Differences in female high and low consumers of sweet/low energy beverages. *J Hum Nutr Diet* 2004, 17, 425-34.
29. de Graaf C. The validity of appetite ratings. *Appetite* 1993, 21, 156-60.
30. De Graaf C, Schreurs A, Blauw YH. Short-term effects of different amounts of sweet and non-sweet carbohydrates on satiety and energy intake. *Physiol Behav* 1993, 54, 833-43.
31. Dalenberg JR, Nanetti L, Renken RJ, de Wijk RA, ter Horst GJ. Dealing with consumer differences in liking during repeated exposure to food; Typical dynamics in rating behavior. *PLoS ONE* 2014, 9, e93350.
32. Weijzen PLG, Zandstra EH, Alfieri C, de Graaf C. Effects of complexity and intensity on sensory specific satiety and food acceptance after repeated consumption. *Food Qual Pref* 2008, 19, 349–359.
33. Zandstra EH, Weegels MF, van Spronsen AA, Klerk M. Scoring or boring? Predicting boredom through repeated in-home consumption. *Food Qual Pref* 2004, 15, 549-557.
34. Rolls BJ. Sensory-specific satiety. *Nutr Rev* 1986, 44, 93-101.
35. Griffioen-Roose S, Finlayson G, Mars M, Blundell JE, de Graaf C. Measuring food reward and the transfer effect of sensory specific satiety. *Appetite* 2010, 55, 648-55.
36. Griffioen-Roose S, Mars M, Finlayson G, Blundell JE, de Graaf C. The effect of within-meal protein content and taste on subsequent food choice and satiety. *Br J Nutr* 2011, 106, 779-88.

37. Frank GK, Oberndorfer TA, Simmons AN, Paulus MP, Fudge JL, Yang TT, Kaye WH. Sucrose activates human taste pathways differently from artificial sweetener. *Neuroimage* 2008, 39, 1559-69.
38. Low YQ, Lacy K, Keast R. The role of sweet taste in satiation and satiety. *Nutrients* 2014, 6, 3431-50.
39. Low JY, McBride RL, Lacy KE, Keast RS. Psychophysical evaluation of sweetness functions across multiple sweeteners. *Chem Senses* 2017, 42, 111-120.
40. Coolican H. *Research Methods and Statistics in Psychology* (7th edition). Routledge: Abingdon, UK.

Table 1: Details of the foods provided in the taste test (taste, texture, weight and energy provided)

Foods¹	Taste	Texture	Weight provided (grams)	Energy provided (kj)	Energy provided (kcal)
Apple Juice	Sweet	Liquid	12	25	6
Madeleine Cake	Sweet	Solid	4	77	18
Tinned Peaches	Sweet	Soft-solid	12	20	5
Low Fat Natural Yoghurt	Non-sweet	Soft-solid	10	33	8
Cucumber	Non-sweet	Solid	10	6	1.5
Medium Cheddar Cheese	Non-sweet	Solid	5	87	21
Total			53	248	59.5

¹All foods were manufactured for *Sainsbury's Supermarkets Ltd., London, UK*, with the exception of the Madeleine Cakes, which were manufactured by *Bon Maman, Contres, France*.

Table 2: Details of the foods provided in the buffet meal (taste, weight and energy provided)

Foods¹	Taste	Weight provided (grams)	Energy provided (kJ)	Energy provided (kcal)
Bread	Non-sweet	250 (6 slices)	2478	592
Butter	Non-sweet	1 pot ² (150-240g)	3630 – 7260	867 – 1734
Strawberry Jam	Sweet	1 pot ² (250-440g)	2403 – 4806	574 – 1148
Honey	Sweet	1 pot ² (160-330g)	2377 – 4753	568 – 1136
Peanut Butter	Non-sweet	1 pot ² (250-440g)	6014 - 12028	1437 - 2874
Madeleine Cake	Sweet	100 (4 cakes)	1916	458
Tinned Peaches (Drained)	Sweet	240	487	116
Cucumber	Non-sweet	120	74	18
Medium Cheddar Cheese	Non-sweet	100	1725	412
Low Fat Natural Yoghurt	Non-sweet	250	483	115
Apple Juice	Sweet	500	2500	597
Water	Non-sweet	1000	0	0
Total			24087 - 38510	5754 – 9200

¹All foods were manufactured for *Sainsbury's Supermarkets Ltd., London, UK*, with the exception of the Bread, which was manufactured by *KingsMill 50/50, Allied Bakeries, Maidenhead, UK*; the Butter, which was manufactured by *Lurpak spreadable, Arla Foods, Denmark*; the Peanut Butter, which was manufactured by *Whole Earth, Kallo Foods Ltd., Surrey, UK*; and the Madeleine cakes, which were manufactured by *Bon Maman, Contres, France*.

²Variable amounts provided in standard manufacturer's jars that ranged from half-full to complete

Table 3: Descriptive statistics for all participants in the sweet taste (N=27) and non-sweet taste (N=27) exposure groups¹

Exposure Group	Sweet Taste (N=27)	Non-Sweet Taste (N=27)
Background Characteristics		
Gender (N (%))	9 M (33%), 18 F (67%)	9 M (33%), 18 F (67%)
Age (years)	24.2 (7.0)	23.5 (4.4)
Bmi (kg/m ²)	24.0 (3.9)	23.2 (3.2)
Habitual Breakfast (N (%))	14 Sweet (52%), 13 Non-sweet (48%)	13 Sweet (48%), 14 Non-sweet (52%)
Ratings For Sweet And Non-Sweet Foods (100mm VAS)		
Sweet Food Pleasantness (0-100)	69 (13)	69 (19)
Sweet Food Desire To Eat (0-100)	60 (18)	63 (25)
Sweet Food Sweetness (0-100)	65 (14)	69 (17)
Non-Sweet Food Pleasantness (0-100)	58 (18)	53 (17)
Non-Sweet Food Desire To Eat (0-100)	49 (19)	49 (19)
Non-Sweet Food Sweetness (0-100)	21 (18)	19 (15)
Breakfast Intake		
Weight Of Food Consumed (g)	644 (413)	597 (391)
Percent Weight From Sweet Foods (%)	27 (15)	29 (20)
Energy Consumed (kJ)	2355 (1421)	2575 (1489)
Percent Energy From Sweet Foods (%)	34 (14)	30 (16)
Sugars Consumed (g)	28 (20)	25 (18)
Percent Energy From Sugars (%)	16 (7)	12 (6)

¹ Values are mean ± SD, unless otherwise stated

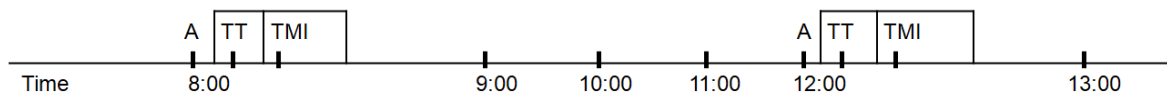


Figure 1: Diagram of the study procedure for each test day¹.

¹ A: Appetite ratings (Hunger, Fullness, Thirst); TMI: Test Meal Intake; TT: Taste Test

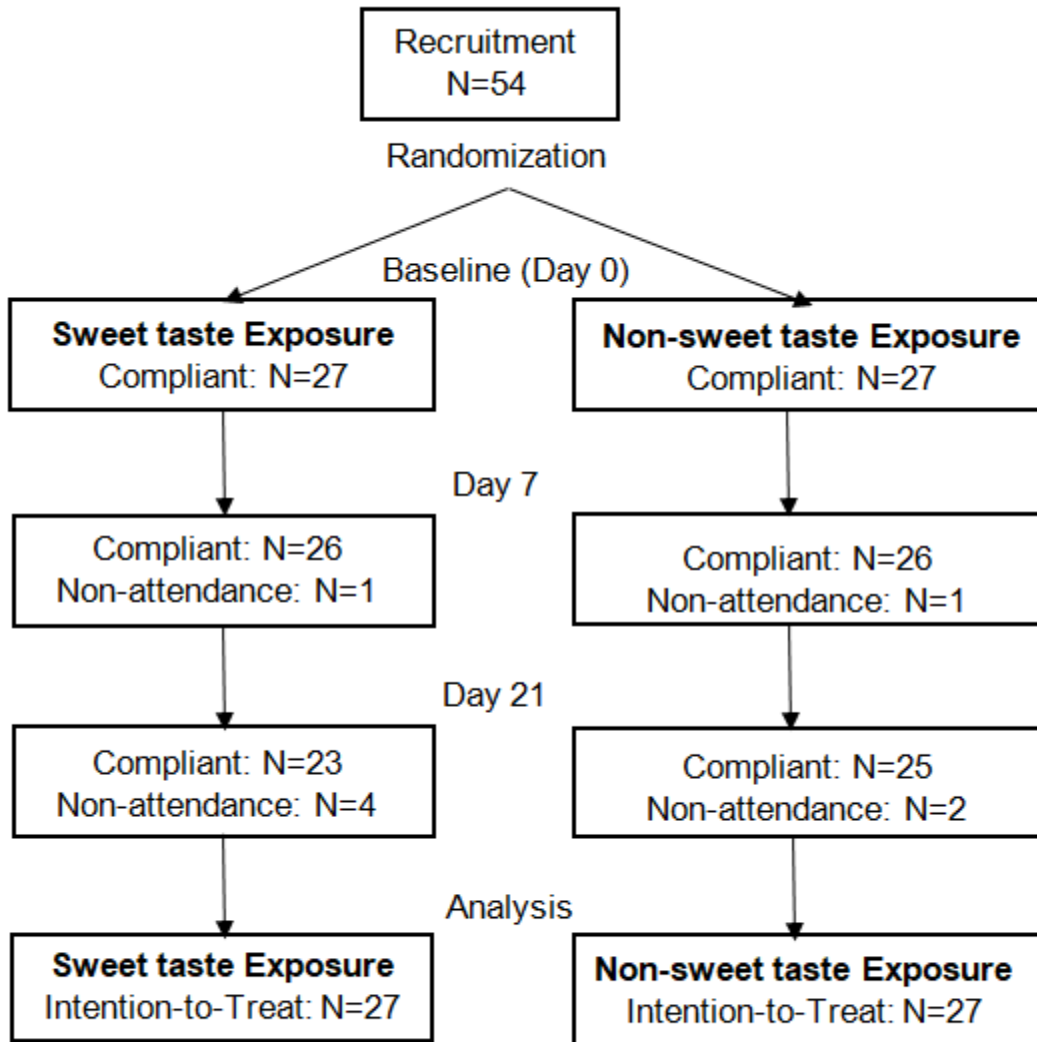


Figure 2: CONSORT flow diagram, detailing participant flow through the trial, N=54.

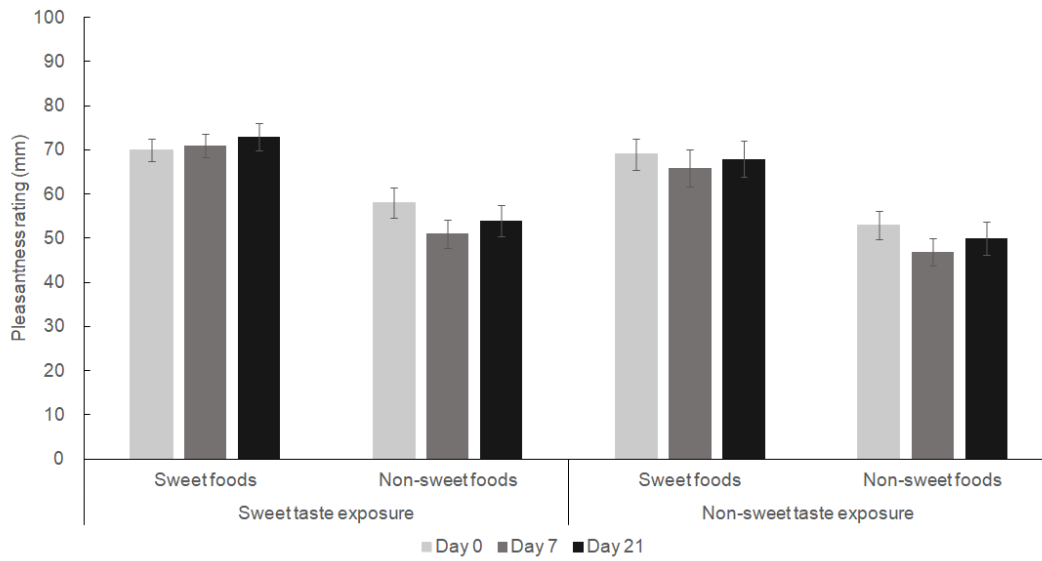


Figure 3: Pleasantness ratings during the taste test at breakfast for sweet and non-sweet foods on days 0, 7 and 21, following sweet taste or non-sweet taste exposure. Values are mean \pm SE, N=54. Sweet and non-sweet foods differ when exposure groups and time points are combined, $p < 0.01$; no significant differences between exposure groups.

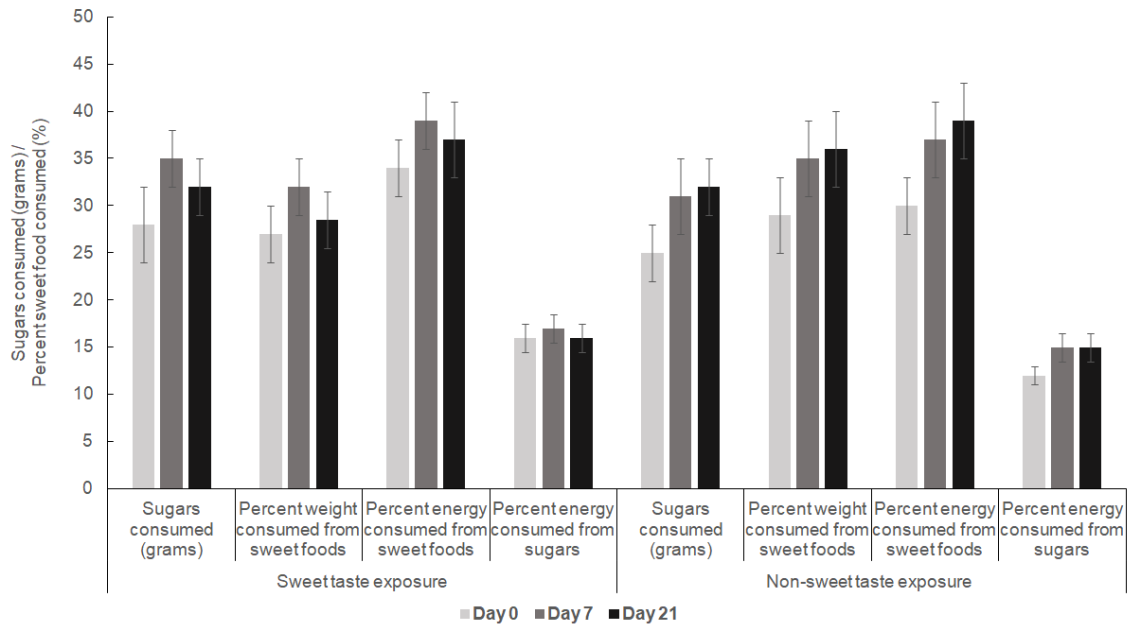


Figure 4: Food intake (sugars, percent weight consumed from sweet foods, percent energy consumed from sweet foods, percent energy consumed from sugars) at breakfast on days 0, 7 and 21, following sweet taste or non-sweet taste exposure. Values are mean \pm SE, N=54. Percent energy consumed from sweet foods (and sugars consumed) differ over time when sweet taste and non-sweet taste exposure groups are combined, $p=0.01$; no significant differences between exposure groups.