How full am I? The effect of rating fullness during eating on food intake, eating speed and relationship with satiety responsiveness.

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Abstract

Modifying eating behaviours may be an effective strategy to limit excess food intake, such as eating slower and mindfully. We hypothesized that regularly rating fullness whilst eating a standard meal in one course would increase post-meal satiety and reduce intake in a subsequent course during the same sitting. A between-subjects design was employed (n=65; 75% female; mean age=26.7 (s.d.=9.5); mean body mass index=22.4 (s.d.= 3.3)), with three conditions of within-meal visual-analogue-scale ratings: 'Fullness' (rated fullness); 'Taste' (rated pleasantness of taste of food); 'Control' (rated comfort of room). Fasted participants ate a pasta meal (327 kcal) followed by cookies *ad libitum*. Appetite ratings were measured at baseline, following each course and for 3-hours post-meal. Satiety responsiveness was measured using the Adult Eating Behaviour Questionnaire, Intuitive Eating Scale and by calculating the satiety quotient of the pasta course alone and the whole meal. The primary outcomes were fullness ratings post-pasta course [mean (s.d.): Fullness=67.1 (21.9); Taste=64.4 (13.7); Control=60.2 (21.5)] and cookie intake [mean kcal (s.d.): Fullness=249 (236); Taste=279 (231); Control=255 (208)]. Eating speed was included as a secondary, control outcome [mean (s.d.): Fullness=59.3 (9.0); Taste=59.2 (17.7); Control=60.7 (19.6)]. No evidence for a difference in outcomes was identified between conditions ($p>0.05$). Future work could involve testing the impact of rating fullness during multiple meals over a longer period. Secondly, this study explored whether levels of satiety responsiveness influenced the impact of the manipulation on outcomes; however only weak evidence for a relationship with eating speed was found. Finally, only a weak relationship was found between the satiety responsiveness measures, suggesting that different aspects of the underlying construct are being captured.

Keywords: satiety; fullness; food intake; eating speed; satiety responsiveness

1. Introduction

A novel approach to the current obesity crisis is to focus on how to improve eating behaviour rather than modifying diet and exercise alone. Strategies focusing on mindful (Tapper, 2017) or attentive (Robinson, Aveyard, et al., 2013) eating have been examined, in addition to training response inhibition towards high energy-dense foods (Adams, Lawrence, Verbruggen, & Chambers, 2017), and slowing eating rate (Robinson et al., 2014). Several studies in the latter review used a device known as the Mandolean® (or Mandometer®) to control the speed of eating (Ioakimidis, Zandian, Bergh, & Sodersten, 2009; Karl, Young, & Montain, 2011; Karl, Young, Rood, & Montain, 2013; Zandian, Ioakimidis, Bergh, & Sodersten, 2009; Zandian et al., 2012). The Mandolean® is a computerised weighing scale, which provides continuous verbal and visual feedback on a small computer or smart phone during meals. Training with the Mandolean® also incorporates ratings of fullness (every 1.5 minutes) during each meal. These fullness ratings appear visually on the Mandolean® computer screen, which allows comparison to a 'normal' fullness curve pre-set on screen (Bergh, Brodin, Lindberg, & Sodersten, 2002). Patients learn to associate their feeling of fullness with the fullness training curve (see Figure 1 in Ford et al., 2010). Indeed, twelve-months training with the Mandolean® led to reduction in meal size but with no reduction in fullness following those meals (Ford et al., 2010), suggesting increased perception of fullness following training. This finding led to the current research question: might simply rating fullness regularly during a meal serve to increase perception or responsivity to fullness, and if so, would this lead to a reduction in subsequent food intake? If this was the case, the findings could be used to design a simple, widely applicable intervention to improve responsiveness to fullness signals.

Satiety responsiveness encapsulates the extent to which an individual is aware of their internal hunger and fullness cues and uses those cues to guide their eating behaviour. Questionnaires, such as the Child Eating Behaviour questionnaire (Wardle, Guthrie, Sanderson, & Rapoport, 2001), the corresponding Adult Eating Behaviour questionnaire (AEBQ; Hunot et al., 2016), and the Intuitive Eating Scale (IES2; Tylka & Kroon Van Diest, 2013) have been used to measure this trait. Satiety responsiveness has been found to be associated with lower food intake (Camilleri et al., 2017) and negatively correlated with BMI in adults (Camilleri et al., 2016; Hunot et al., 2016; Mallan et al., 2017). An alternative approach has been to measure the extent to which subjective appetite changes following consumption of foods (Drapeau et al., 2013); known as the satiety quotient (SQ; Green, Delargy, Joanes, & Blundell, 1997). A recent systematic review has demonstrated the reliability of the SQ to predict food intake and the negative association with body weight, but also the utility of the measure to categorise individuals according to their tendency to use appetitive cues to drive intake (Fillon et al., 2020).

The primary aim of the current study was to take the 'fullness' aspect of the Mandolean® training alone (i.e. not to manipulate eating rate) to address the question of whether regular ratings of fullness throughout a single meal could lead to increased fullness following that meal and a reduction in subsequent food intake, accordingly. Within-meal ratings of fullness were compared with ratings of pleasantness of taste and a control rating in a between-subjects design. We postulated that the ratings of fullness may draw the participants' attention towards fullness sensations, such that they would be primed on their developing fullness, as opposed to other sensations such as pleasantness of the food. Specifically, it was hypothesized that compared to the taste and control ratings, regularly rating fullness during a fixed pasta meal would lead to increased fullness post-meal and reduce food intake during a second, *ad libitum* course (Hypothesis 1). Several secondary aims were also specified: First, eating speed (grams/minute) was incorporated as a secondary, control outcome in case of systematic differences between the time taken to give the meal-time ratings in each condition (Fullness, Taste and Control), in the light of research showing decreased intake after eating more slowly (Robinson et al., 2014). Secondly, this study was designed to explore whether individual levels of satiety responsiveness would influence the impact of the within-meal ratings on post-meal fullness and intake. It was hypothesised that those with higher responsiveness to satiety in the Fullness condition would give higher fullness ratings following the meal and eat less at the second course (Hypothesis 2). Thirdly, through exploratory analyses, we also examined whether any of the satiety responsiveness measures (AEBQ, IES2 or SQ) would show a positive association with post-meal fullness or a negative association with cookie intake in the whole sample (Hypothesis 3). Finally, this study provided an opportunity for a novel examination of the relationships between responses on the three measures of satiety responsiveness. We predicted positive associations between the AEBQ_SR subscale, IES2 Reliance on hunger and satiety cues subscale and SQ scores, which would suggest that these scores measure a similar underlying construct (Hypothesis 4).

2. Materials and Methods

2.1 Participants

Seventy-two healthy adults were recruited into this study. Participants were recruited by posters displayed on university noticeboards, word of mouth, and through the School of Experimental Psychology's web page 'Taking part in our experiments'. Exclusion criteria were as follows: history of psychiatric or eating disorders; diabetes; food allergies; currently on a diet to control weight (whether attempting to lose or gain weight); BMI 18 or below, or 30 or above; not fluent in English; not willing to abstain from eating and consuming energy-containing beverages for 3 hours before and 3 hours after the session; vegan; taking any medication that may influence appetite (except oral contraceptive pills); smoking more than 5 cigarettes a day. These exclusion criteria were checked

using an initial screening form prior to the testing session. This study was approved by the Faculty of Science Human Research Ethics Committee at the University of Bristol.

2.2 Design

A between-subjects design was employed, with three experimental conditions. Each condition comprised giving subjective ratings using computerised visual analogue scale (VAS; 100 mm line with the endpoints 'Not at all' and 'Extremely') every 1.5 minutes during their pasta meal. Each condition required a different within-meal rating: (1) in the 'Fullness' condition, participants were required to give a satiety rating with the question "How full do you feel right now?". This was the main condition of interest. (2) in the 'Taste' condition, participants were required to rate how pleasant the food tasted with the question "How pleasant does this food taste in your mouth RIGHT NOW?". This condition was included to assess the extent to which sensory-specific satiety may occur over the course of the meal. (3) in the 'Control' condition, participants were asked to rate how comfortable the room was with the question "How comfortable do you feel in this room right now?". This condition controlled for the time taken to make a rating in the other two conditions, which was unrelated to the meal itself. Participants were randomised into each condition using a blocked randomisation list (based on male/female) on Sealed Envelope (https://www.sealedenvelope.com/). For consistency, the name 'Fullness' will be used to refer to the experimental condition, and the term 'fullness rating' will be used to refer to the subjective sensation throughout. Similarly, the name 'Taste' will refer to the experimental condition, and the term 'pleasantness' will refer to the subjective sensation throughout.

A power calculation was conducted using change in fullness ratings (from baseline to post-intervention) in a similar unpublished study with two experimental conditions conducted at the Nutrition and Behaviour Unit at the University of Bristol (Cohen's d = 0.84; large effect size). G*Power was used with the following options: 'a priori option to compute sample size given alpha, power and effect size' for a 'mean difference between two independent means'. With an effect size of Cohen's d = 0.84, type I error rate of 0.05 for a two-tailed test, a total sample size of 48 (24 in each condition) yields a minimum 80% power. Therefore, we aimed to recruit 24 participants in each condition, with a total sample size of 72.

2.3 Procedure and Measures

Participants were instructed to eat their normal breakfast, then not to consume food or energy-containing beverages for three hours prior to their study session. The cover story for the study was that "the effect of mood on appetite and food intake" was to be investigated. Individual participant test sessions were scheduled between 1200 and 1400 hours on weekdays. Figure 1 shows a timeline for the study session. On arrival, all participants provided informed consent. A check to confirm that participants had fasted as requested and details of their breakfast were recorded. A demonstration was given of how to complete the VAS ratings on the computer.

First, participants completed baseline appetite ratings: “How hungry do you feel right now?”; “How full do you feel right now?”. A 100 mm line was presented on screen with the endpoints “Not at all” on the left and “Extremely” on the right. The participant moved a cursor along the line using the keyboard to the position that best represented how they felt on each dimension at that moment. In keeping with the cover story, the participant was then given a series of mood ratings to complete in the same computerised VAS format. These MAPS mood ratings have been reported previously (Ferriday et al., 2015). For the purposes of this paper, these ratings were not analysed. The MAPS data can be viewed in Supplementary Materials.

The pasta meal (Be Good to Yourself Mediterranean vegetable pasta, 351 kcal portion, energy density = 0.9 kcal/g) and 200 ml water were given to participants. Participants were asked to eat one mouthful of the pasta meal, and to give the following ratings: "How pleasant does this food taste in your mouth RIGHT NOW?", and "Now look at the food in front of you. How strong is your desire to eat, that is, to taste, chew and swallow, the food RIGHT NOW?"(Rogers & Hardman, 2015). Participants were told: “Please remember to pay attention to the screen whilst eating all of your meal and follow the instructions. Please press ‘S’ as soon as you have finished”. Participants then pressed a key to start the timer on the computer programme and ate their meal at their own pace (then pressed the ‘S’ key at the end of the meal). The programme recorded the time taken to eat the meal. During the pasta meal, ratings were requested every 1.5 minutes according to each condition (Fullness: "How full do you feel right now?"; Taste: "How pleasant does this food taste in your mouth RIGHT NOW?" Control: "How comfortable do you feel in this room right now?"). The plate and pasta were weighed before and after meal such that the amount consumed could be calculated. Eating rate (g/min) was calculated: pasta consumed (grams) / length of time taken to eat pasta meal (mins).

All participants completed a further fullness rating (wording as before, primary outcome). Participants were then given a large bowl of broken chocolate chip cookies (Chocolate chip cookies by Sainsburys, 1972 kcal portion, energy density = 4.9 kcal/g) and asked to follow instructions on screen to complete the pleasantness and desire to eat ratings after one mouthful of cookie (as above). The instruction was then given: “Now it’s time to eat your dessert. Please eat until you feel comfortably full. Please press ‘S’ as soon as you have finished.” Participants completed pleasantness and desire to eat cookie ratings, post-meal appetite ratings and the final set of mood ratings (for the cover story). The bowl, cookies (primary outcome), glass and water were weighed before and after the meal such that amount consumed could be calculated.

The AEBQ was completed; this questionnaire is a reliable measure of eight appetitive traits (Cronbach’s alpha > 0.70; Hunot et al., 2016), including satiety responsiveness (AEBQ_SR) that was used in the analysis for this paper. The IES2 was also completed; this questionnaire measures four aspects of intuitive eating (Cronbach’s alpha > 0.80; Tylka & Kroon van Diest, 2013). Only the

reliance on hunger and satiety cues subscale was used in analyses (IES2_Reliance). A comparison between satiety responsiveness items across these two questionnaires is provided in Table 1. After removing shoes, height was recorded using a stadiometer and weight was recorded using a calibrated weighing scale for calculation of BMI. Participants were then asked to describe in writing in as much detail as possible what they believed was the aim of the study to assess their awareness of the study design. Finally, they were given paper VASs to measure hunger and fullness 1-, 2- and 3-hours post-meal. As participants could leave the laboratory at this stage, the time the VAS should be completed was written on the top of the sheet, an email reminder was sent 10 minutes prior to the rating, and participants were asked to set a timer on their mobile phone if possible. Once all the data had been collected, debriefing information was sent out to participants by email. The debriefing information explained that the rationale of the study was to investigate whether increasing awareness of fullness by asking people to rate how full they are feeling during a meal would lead to them feeling more full after the meal and subsequently eating less food.

Table 1: Satiety responsiveness items from the AEBQ and IES2 questionnaires

AEBQ Satiety responsiveness items	**IES2 Reliance on hunger and satiety cues subscale**
I often leave food on my plate at the end of a meal	I trust my body to tell me when to eat.
I often get full before my meal is finished	I trust my body to tell me what to eat.
I cannot eat a meal if I have had a snack just before	I trust my body to tell me how much to eat.
I get full up easily	I rely on my hunger signals to tell me when to eat.
	I rely on my fullness (satiety) signals to tell me when to stop eating.

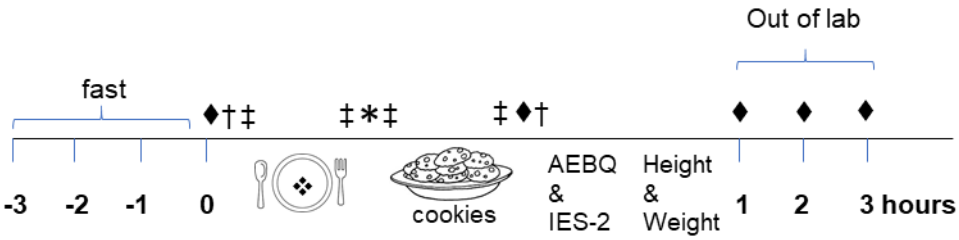

Figure 1: Timeline of test session.

Key: ♦ Appetite ratings ("How hungry do you feel right now?"; "How full do you feel right now?"); † Mood ratings (MAPS; Supplementary Materials); ‡ Taste/Desire to eat ratings ("How pleasant does this food taste in your mouth RIGHT NOW?", and "Now look at the food in front of you. How strong is your desire to eat, that is, to taste, chew and swallow, the food RIGHT NOW?"); ❖ Within-meal ratings (Fullness: "How full do you feel right now?"; Taste: "How pleasant does this food taste in your mouth RIGHT NOW?" Control: "How comfortable do you feel in this room right now?"); * Post-pasta meal fullness rating ("How full do you feel right now?").

2.4 Statistical Analysis

First, eating speed was calculated by the following formula: pasta consumed (grams)/time to eat pasta (minutes). Consideration was given to potentially important covariates for these analyses. Given it is important to control for potential differences in baseline appetite ratings between groups; pre-meal fullness was added as a covariate in the adjusted model. A difference in BMI was found between the conditions ($p = 0.03$). In an unadjusted model, pairwise comparisons (Tukey HSD) showed that there was a difference in BMI between the Fullness and Taste conditions ($p = 0.03$), but no difference between Fullness and Control conditions ($p = 0.82$), nor between Taste and Control conditions ($p = 0.13$). For this reason, BMI was added as a covariate to control for this difference in the analyses. The satiety responsiveness subscale of the AEBQ (AEBQ_SR) also differed between conditions ($p = 0.01$). In an unadjusted model, a difference was found between the Fullness and Control conditions ($p = 0.03$) and Taste and Control conditions ($p = 0.01$), but not between Fullness and Taste conditions ($p = 0.93$). For this reason, satiety responsiveness was added as a covariate to control for this difference in the analyses.

To address the first hypothesis, a series of ANCOVAs were conducted to compare the means of the outcome variables (post-pasta fullness, cookie intake (kcal), eating speed) between the three conditions. To control for the effect of potential confounders (age, sex, pre-meal fullness, AEBQ_SR and BMI), two different models were implemented: Model 1 was unadjusted, including condition as a fixed factor only. Model 2 included condition as a fixed factor and was adjusted for sex (fixed factor)

and pre-meal fullness, age, BMI and AEBQ_SR as covariates. Due to the known differences in eating behaviour between males and females (e.g. Kiefer, Rathmanner, & Kunze, 2005), evidence for interactions between outcomes and sex were reported. For the second hypothesis, evidence for an interaction between AEBQ_SR, IES2_Reliance, and SQ_wholemeal and post-pasta fullness and cookie intake was reported. A Chi square test was used to assess whether any awareness of the study design was evenly distributed across conditions.

The satiety quotient of the pasta course and the whole meal (pasta +cookies) were calculated separately for each participant using the meal time ratings as follows: (i) SQ of pasta meal = (baseline fullness – post-pasta fullness) / pasta consumed (kcal); (ii) SQ of whole meal = (baseline fullness – post-meal fullness*) / total consumed kcal. [*average of ratings taken at 0, 1-, 2- and 3-hours post-meal, reported in Figure S2]. Fullness ratings were chosen as the appetite rating to complete the SQ calculation as this was only the appetite sensation measured between the two courses (Drapeau et al., 2007).

To address the third hypothesis, Pearson's correlation was employed using the overall sample not split by condition to assess the relationship between fullness post-pasta[#], cookie intake and eating rate with measures of satiety responsiveness (AEBQ_SR, IES2_Reliance, and SQ of pasta meal and SQ of wholemeal). [[#]To control for baseline levels of fullness in these analyses, a change from baseline variable was calculated using the following formula: post_pasta_fullness - premeal_fullness]. To address the fourth hypothesis, Pearson's correlation was used to examine the relationship between AEBQ_SR and IES2_Reliance and SQ. As this was an exploratory analysis involving multiple correlations, the p value used to consider the level of evidence for each correlation was adjusted using the Bonferroni correction (0.05/17 = 0.003). The results were described based on the usual cut-offs for considering the size of effect using values of r (0.1 = small; 0.3 = medium; 0.5 = large).

3. Results

3.1 Baseline characteristics

The design of the experiment required that participants across conditions consumed the same amount of food in the first course pasta meal. Seven participants (three from Fullness condition; two from each of the Taste and Control conditions) were removed from the full sample as outliers (two or three standard deviations from the mean pasta consumed (kcal); either because they did not finish their meal or because they were given too much in error. Table 2 shows the baseline characteristics for the final sample in each condition.

Table 2. Means (standard deviation) for baseline measures

Measures	Fullness	Taste	Control
N	22	22	21
Sex (% female)	77.3%	68.2%	81.0%
Age (years)	30.4 (11.7)	24.3 (7.7)	25.5 (7.9)
BMI (kg/m^2)	23.4 (3.7)	20.9 (2.3)	22.8 (3.4)
Time since last eating (hr:min)	4:35 (0.4)	4:35 (0.5)	4:22 (0.4)
Baseline fullness (VAS 0-100mm)	37.7 (32.1)	22.5 (17.6)	27.4 (24.4)
Baseline hunger (VAS 0-100mm)	74.5 (21.6)	73.5 (15.5)	69.4 (15.9)
AEBQ_SR (score 1-5)	2.5 (0.7)	2.6 (0.7)	2.0 (0.7)
IES2_Reliance (score 1-5)	3.5 (0.9)	3.3 (0.6)	3.4 (0.8)

NB. Data for all subscale scores from the AEBQ and IES2 can be found in the Supplementary Materials.

3.2 Meal-time variables and appetite ratings

Table 3 and Figure S2 report the measures collected during and after the meal for each condition separately. Between conditions, no differences were observed in the amount of pasta consumed in the first course ($p = 0.25$) or number of ratings completed during the meal ($p = 0.13$); Fullness: median = 3, IQR = 0.3; Taste: median = 3, IQR = 1.0; Control: median = 4, IQR = 1.0).

Table 3. Means (standard deviation) for meal-time variables during the test session

Measures	Fullness	Taste	Control
Total pasta consumed (kcal)	323.9 (13.1)	327.5 (14.3)	330.2 (11.9)
Water consumption (ml)	198.9 (38.6)	194.2 (50.1)	192.7 (45.7)
Pleasantness of pasta (VAS 0-100mm) [1]	80.7 (18.3)	75.0 (14.6)	71.6 (15.7)
Desire to eat pasta (VAS 0-100mm) [1]	79.1 (22.4)	76.5 (14.9)	75.6 (14.5)
Pleasantness of cookies (VAS 0-100mm) [1]	72.5 (16.1)	73.3 (14.8)	68.2 (18.9)
Desire to eat cookies (VAS 0-100mm) [1]	53.9 (26.4)	57.9 (28.5)	61.5 (24.8)
Satiety quotient (pasta only)	-.09 (.11)	-.12 (.08)	-.10 (.09)
Satiety quotient (whole meal)	-.04 (.07)	-.07 (.04)	.06 (.04)

[1] Ratings taken during initial taste test prior to eating each food.

3.3 Primary outcomes

The results of the three outcome variables are reported in Table 4. Contrary to hypothesis 1, there was no difference in fullness ratings immediately following the pasta meal or the total cookies consumed (kcal) between conditions. There was no difference in eating speed between conditions. There were no interactions between condition and sex for any outcome ($p > 0.2$). There was a sex effect on all three outcomes: (i) males (mean fullness on VAS scale = 51.5; std. error = 5.6) were less full than females (mean fullness on VAS scale = 67.4; std. error = 2.8); (ii) males (mean = 384.3 g; std. error = 57.3) consumed more cookies than females (mean = 223.3 g; std. err = 29.1); (iii) males (mean = 70.9 g/min; std. err = 4.4) ate their meal faster than females (mean = 56.5 g/min; std. err = 2.3).

Table 4. Means (standard deviation) for outcome variables

Measures	**Fullness**	**Taste**	**Control**	**Model 1 p value**[1]	**Model 2 p value**[2]
Fullness post-pasta (VAS 0-100mm)	67.1 (21.9)	64.4 (13.7)	60.2 (21.5)	0.5	0.4
Total cookies consumed (kcal)	249 (236)	279 (231)	255 (208)	0.9	0.9
Eating speed (grams/min.)	59.3 (9.0)	59.2 (17.7)	60.7 (19.6)	0.9	0.7

[1]Model 1 unadjusted condition as fixed factor; [2]Model 2 adjusted condition and sex as fixed factors; pre-meal fullness, age, BMI and AEBQ_SR as covariates. NB. There was a negative correlation between post-pasta fullness and total cookies consumed ($r = -0.32$, $p = 0.01$).

3.4 Awareness of study design

Participants were classified as aware, possibly aware or not aware of the true purpose of the study, following reading of participants' description of the purpose of the study. Eight participants were classed as possibly aware, whilst the others seemed unaware of the main reason for the study. Chi square test showed that there was no difference in the distribution of not or possibly aware between conditions ($X2 = 3.59$; $p = 0.17$); therefore, it is unlikely that this factor may have influenced the above results.

3.5 Relationship between primary outcomes and satiety responsiveness

The second research question asked whether individual levels of satiety responsiveness would influence the impact of the manipulation on post-meal fullness and intake. However, no evidence for an interaction was found in either model for any of the three measures of satiety responsiveness: Fullness post-pasta: AEBQ_SR p = 0.139; IES2_Reliance p = 0.20 ; SQ_wholemeal p = 0.71; Cookie intake: AEBQ_SR p = 0.31; IES2_Reliance p = 0.31; SQ_wholemeal p = 0.37). These results suggest that individual levels of satiety responsiveness did not interact with type of ratings completed during the meal to influence post-meal fullness or subsequent cookie intake.

For the third hypothesis, correlations were conducted across the whole sample (n = 65) between the primary outcome measures (fullness post-pasta, cookie intake and eating speed) and the measures of satiety responsiveness (Table 5).

Table 5. Correlation matrix showing the relationship (r) between measures of satiety responsiveness and primary outcome variables (p value in brackets) for the whole sample (n=65).

	Fullness* post-pasta	Cookie intake	Eating speed	AEBQ_SR	IES2_Reliance	SQ_pasta	SQ_whole-meal
Fullness post-pasta*							
Cookie intake	-.14 (.27)						
Eating speed	-.19 (.14)	-.13 (.30)					
AEBQ_SR	.01 (.94)	-.12 (.35)	-.31 (.01)				
IES2_Reliance	-.23 (.07)	.08 (.55)	.01 (.94)	.11 (.37)			
SQ_pasta	n/a	.15 (.25)	.20 (.12)	-.01 (.94)	.24 (.05)		
SQ_whole-meal	n/a	n/a	-.15 (.24)	.20 (.12)	-.24 (.05)	-.81 (.00)	

*****fullness rating post-pasta meal – baseline fullness rating; n/a: comparisons were deemed not applicable as the values of fullness post-pasta and cookie intake were used to calculate SQ_pasta and SQ_whole-meal, respectively.

Based on the size of the relationships between variables alone, there is a moderate relationship between AEBQ_SR and eating rate whereby those who ate faster reported lower satiety responsiveness scores. However, considering the adjusted p-value ($p < 0.003$), there is only weak evidence for a relationship between the questionnaire measures of satiety responsiveness and the primary outcomes in this study.

3.6 Relationship between measures of satiety responsiveness

As Table 5 shows, there is little evidence for a relationship between the two questionnaire measures of satiety responsiveness in this sample (AEBQ_SR & IES2_Reliance; see Table 1 for items). There is also little evidence for a relationship between AEBQ_SR and SQ pasta, and small correlation with SQ for the whole meal. There is weak evidence for a small correlation between the IES2_Reliance and the two measures of SQ.

4. Discussion

The objectives of this study were three-fold: primarily, the study set out to examine whether regularly rating fullness during a single course of a meal could serve to increase perception of fullness developing during that meal and lead to a reduction in subsequent food consumption during the second course. This is akin to one training meal using the Mandolean®. However, whether participants rated their fullness, pleasantness of the taste of the meal or the comfort of the testing room made no difference to the fullness experienced following the main course nor the amount of cookies consumed in the second course. Secondly, no evidence for a relationship between responsiveness to satiety and within-meal ratings of fullness was found, nor between satiety responsiveness and post-meal fullness and food intake. Finally, only a weak relationship was found between three commonly used measures of satiety responsiveness, suggesting that different aspects of satiety responsiveness are captured by these measures.

There are reasons why post-meal fullness and intake did not differ between conditions. First, the simple act of using a rating scale to indicate how full a person is feeling during a single meal may not serve to increase perception of their internal sensations changing during that meal, as intended. This study attempted to emulate the fullness aspect of the Mandolean® training using a single meal before potentially extending it to multiple meals within a second, longitudinal study. It appears from the results of this first study that any effects of regularly rating fullness cannot be demonstrated during a single meal. Further research could require participants to rate their fullness during several meals over a longer period, in order to comprehensively test whether the fullness aspect of the Mandolean training has independent effects on satiety, rather than purely associated with the reported changes to eating speed (Ford et al., 2010; Galhardo et al., 2012).

It could also be argued that given participants in all three groups rated their fullness at four timepoints during the study session, all participants could have been primed to consider their experience of fullness and not just the Fullness group as intended. However, it should be noted that ratings of hunger were also included at three of those timepoints, and importantly only the Fullness group rated fullness during the meal itself. Yet, this simple ‘intervention’ may have raised general awareness of the present moment in all participants. More explicit instructions to consider internal sensations of fullness developing (stomach filling etc.) may be required to encourage participants to be more

responsive specifically to fullness signals. This is akin to the literature on mindful eating; focussing on the sensory properties of foods has led to reduced consumption of snacks compared to control conditions (Arch et al., 2016; Fisher, Lattimore, & Malinowski, 2016; Seguias & Tapper, 2018).

There are also parallels with the current study to research on attentive eating. It could be argued that the 'Fullness' condition attempted to direct attention towards feelings of satiety, the 'Taste' condition towards sensory aspects of the food, and the 'Control' condition towards aspects of the eating environment. While focused attention can lead to enhanced memory for fullness resulting from a meal (Whitelock, Gaglione, Davies-Owen, & Robinson, 2019), to date, there is no consensus as to whether attentive eating influences subsequent food intake, with evidence supporting this claim (Robinson, Aveyard, et al., 2013); (Higgs & Donohoe, 2011), and research that has not shown this effect (Bellisle & Dalix, 2001; Long, Meyer, Leung, & Wallis, 2011) (Whitelock, Higgs, Brunstrom, Halford, & Robinson, 2018), in line with the current findings. These discrepancies may depend on distinguishing between "mindful attention and attention", with the former being more effective in reducing food intake (Fisher et al., 2016). Future work is needed to clarify the impact of differing levels and type of attention given to the food consumed and associated internal sensations during meals on the amount of fullness experienced and subsequent food intake.

Satiety responsiveness did not appear to influence the fullness experienced following consumption of the pasta meal or amount of cookies consumed in the second course. This is perhaps surprising given the nature of the items included in the questionnaire measures (see Table 1); these items relate directly to relying on fullness signals to indicate when to stop eating and becoming full easily (Hunot et al., 2016; Tylka & Kroon Van Diest, 2013), and that the IES2 has been previously shown to predict food intake (Camilleri et al., 2017). Comparison of the mean scores on the IES2 'Reliance on hunger and satiety cues' subscale in this study with the three studies reported in the original paper suggests that the current sample had a slightly lower level of intuitive eating (Tylka & Kroon Van Diest, 2013). It appears, therefore, that these trait measures do not necessarily correspond with fullness and consumption during a single acute eating episode, and that satiety responsiveness may have limited physiological relevance. It is also possible that this study was underpowered to detect such relationships.

Moreover, this study found little evidence of association between the scores on the three different measures of satiety responsiveness. This exploratory finding (the study was not powered to assess this relationship), suggests that these measures capture different aspects of this concept. It could be argued that the AEBQ_SR scale has a strong behavioural focus with a specific emphasis on becoming full easily. By contrast, the IES2 reliance on hunger and satiety scale places emphasis on the ability to connect to and act upon internal signals such as hunger and fullness. This scale reflects one aspect of 'intuitive eating'; trusting the body to indicate when, what and how much to eat. This is argued to be

an adaptive eating strategy based on the ten principles of intuitive eating proposed by Tribole and Resch (2003). Thirdly, the Satiety quotient is different again by requiring collection of actual meal-time variables (appetite sensations and energy consumed), and has been shown to have clinical utility in identifying those at risk for overeating (Fillon et al., 2020). Careful consideration of the most appropriate measure should be given when designing new studies in this area, based on whether the emphasis of any new study is on strong or weak interoception or behaviour.

The limitations of this study should be noted. By including both males and females in order to increase the generalisability of the results, greater variability in the satiating effects of the fixed meal was introduced. While males and females were randomised across conditions in the current study, future work could employ a within-subjects design. Also, rather than the fixed meal design employed in this study, individual differences in energy needs could be used to calculate the requirements of the first course to standardise intake across participants. This alternative design would allow intake of the same course in which the within-meal ratings were given to be measured. The choice of a palatable dessert food as the primary intake outcome may have led to increased consumption regardless of fullness experienced following the pasta meal (Hetherington, 2007). The study could be repeated with a different choice of foods to test that assumption, or the effect of the ratings manipulation could be tested on subsequent consumption in the form of a later taste test rather than a second course. Finally, other appetitive traits, such as cognitive restraint, may have been influencing food intake or fullness in this study and should be considered in future work.

In conclusion, this study demonstrated that simply rating fullness regularly during a meal did not serve to increase perception of fullness nor impact amount consumed in a second course. By only including a single eating episode, the 'fullness' aspect of the Mandolean training was over-simplified. Future work could involve testing the impact of fullness ratings over multiple meals over a longer period. Moreover, the lack of support for the predictions was not explained by trait levels of satiety responsiveness as measured using three different methods. Potential targets for research to promote perception of satiety could include mindfulness training (Tapper, 2017) and attentive eating (Robinson, Higgs, et al., 2013), or extending the current paradigm to include a period of training with satiety curves (akin to Mandolean training) (Ford et al., 2010).

Competing interests statement:

The authors have no competing interests to declare.

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Author Contributions:

ECH designed the study, conducted some data collection, conducted the data analysis and wrote the manuscript. LC conducted the majority of the data collection and facilitated the data analysis. SDL provided advice on the statistical analysis. PJR provided helpful discussions on the interpretation of the data and commented on the manuscript. JHS aided the design of the study and made helpful contributions to the write-up. All authors commented on and approved the final version of the manuscript.

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Data availability statement:

Anonymised data from this study is available upon request from the corresponding author.

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Supplementary Materials

(i) Mood and physical symptoms (MAPS)

Participants completed computerised ratings (100mm visual analogue scales with heading "I feel..." or "My...", and anchor points: "Not at all" and "Extremely") using the following descriptors: nauseous, tense, mentally alert, heart is racing, hot, physically tired, clear headed, miserable, stressed, friendly, mentally fatigued, relaxed, strange, sleepy, energetic, head aches, able to take on a physically demanding task, able to concentrate, angry, lethargic, and cheerful.

	Fullness				Taste				Control			
	Pre-meal		Post-meal		Pre-meal		Post-meal		Pre-meal		Post-meal	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Fullness	37.73	32.09	80.71	13.96	22.45	17.64	79.23	12.07	27.43	18.91	78.24	12.38
Hunger	74.50	21.56	9.59	11.60	73.50	15.51	9.59	15.17	69.43	15.87	14.24	19.06
Thirst	52.86	20.86	52.09	26.65	63.05	21.11	47.14	24.48	64.29	15.02	56.33	21.74
Nauseous	8.64	17.31	11.18	15.58	18.27	23.20	13.95	16.28	17.05	25.66	13.05	21.10
Tense	26.59	27.16	8.91	11.16	39.64	28.62	18.41	18.05	35.38	24.24	22.10	24.70
Alert	54.64	24.57	58.27	21.88	50.14	26.93	63.14	20.45	56.43	24.90	58.90	18.23
Hot	38.77	25.09	44.55	23.41	45.95	28.67	45.41	29.15	41.81	22.79	44.71	27.32
Heart racing	16.82	21.06	15.86	16.10	24.45	24.58	17.77	17.73	23.05	20.59	20.43	20.76
Tired	46.91	26.25	43.86	23.55	54.41	24.49	45.68	20.05	55.00	24.95	48.14	24.15
Clear	57.86	27.56	63.14	18.92	47.91	24.21	60.14	15.82	49.05	22.18	60.95	17.65
Miserable	15.95	20.34	9.23	15.42	28.23	23.80	17.64	19.85	26.76	25.22	14.67	18.01
Stress	36.18	31.00	15.59	19.27	51.59	24.81	30.09	23.96	40.00	28.97	27.71	26.76
Friendly	70.86	24.23	74.64	22.03	63.55	22.87	70.82	16.11	59.10	16.03	62.62	16.44
Fatigued	41.82	31.76	43.23	24.25	57.55	28.49	43.59	24.19	50.43	23.31	38.43	20.34
Relaxed	57.45	25.07	73.45	20.72	52.09	25.24	70.55	14.89	56.62	18.79	68.57	18.52
Strange	18.86	27.32	15.91	22.86	33.45	29.29	22.18	22.82	34.48	30.31	17.29	22.06
Sleepy	46.41	28.07	51.64	26.27	57.27	26.24	51.45	17.90	53.76	25.01	54.33	26.36
Energetic	45.00	24.30	49.86	20.76	40.77	22.69	49.14	16.02	39.48	22.52	41.90	21.79
Head aches	11.73	19.97	14.05	19.80	27.68	27.91	19.36	24.63	19.76	25.60	6.14	14.33
Demanding task	50.82	28.47	59.45	25.93	42.68	24.02	55.05	21.12	45.14	29.10	44.95	28.85
Concentrate	53.36	26.53	63.59	21.99	52.59	24.58	62.55	17.50	53.29	22.08	61.14	15.48
Angry	8.95	18.46	4.86	8.63	18.95	27.62	12.59	21.74	10.76	16.49	7.90	14.75
Lethargic	44.55	30.35	41.27	27.48	50.41	32.70	40.59	24.59	53.71	23.56	54.24	24.43
Cheerful	64.50	24.34	73.95	24.17	58.23	25.90	66.27	17.09	54.57	19.04	63.38	14.70

(ii) Adult Eating Behaviour Questionnaire (AEBQ) and Intuitive Eating Scale (IES2) scores

	Fullness		Taste		Control	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
N	22		22		21	
AEBQ						
Enjoyment of food	4.68	0.47	4.44	0.65	4.71	0.47
Emotional over-eating	2.45	0.89	2.51	0.67	2.87	1.03
Emotional under-eating	3.31	0.89	2.95	0.84	2.60	1.10
Food fussiness	1.63	0.57	1.89	0.68	1.97	0.69
Food responsiveness	3.00	0.95	2.83	0.70	3.48	0.58
Slowness in eating	2.84	0.94	2.89	0.94	2.43	0.83
Hunger	3.18	0.74	3.48	0.65	3.69	0.59
Satiety Responsiveness	2.50	0.73	2.57	0.65	1.98	0.52
IES2						
IES2 Total score	3.69	0.57	3.49	0.33	3.37	0.50
Unconditional permission to eat	3.93	0.85	3.52	1.21	4.08	1.32
Eating for physical rather than emotional reasons	3.74	0.92	3.79	0.86	3.04	1.16
Reliance on hunger and satiety cues	3.54	0.88	3.29	0.59	3.37	0.75
Body-food choice congruence	3.88	0.79	3.71	0.71	3.60	0.82

(iii) Figure S2: Self-report appetite ratings taken after the lunch meal