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# The effect of stealth vs. declared reductions to lunch meal portion size on subsequent energy intake: A randomised control experiment.

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ABSTRACT

Large reductions to meal portion size result in reduced daily energy intake due to reductions not being fully compensated for through later energy intake. However, to date no studies have investigated how relatively small portion size reductions (15 %) affect daily energy intake. The present study investigated whether reducing the portion size of a meal by 15 % affects subsequent intake and if this effect differs depending on awareness of the portion size reduction. Participants ($N = 110$) attended two test days where they were given ad libitum access to a lunch meal and a dinner meal. Portion size of the lunch main course on the second test day was either the same as the amount they had consumed on the test first day (control condition), or 15 % less. Participants served 15 % less were either told that the portion size was the amount they consumed on the previous test day (reduced unaware condition) or it had been reduced (reduced aware condition). Findings revealed that lunch main course intake on the second day was lower in both of the reduced portion size conditions than the control condition. Both immediate and later subsequent intake post-lunch main course did not differ between groups, indicating a lack of evidence for compensatory eating in response to reduced portion size. However, exploratory analyses suggested that participants in the reduced aware condition showed some degree of compensatory eating. These findings suggest that reducing meal portion size by 15 % decreases meal intake and may not cause significant later compensatory eating.

**Trial registration:** This trial was registered at www.clinicaltrials.gov as NCT06119295

## 1. Introduction

Portion size of food is a reliable determinant of energy intake (Hollands et al., 2015; Zlatevska et al., 2014). This tendency for individuals to consume a greater amount of food when served a larger portion is known as the 'portion size effect'. Research has demonstrated the robustness of this effect, with the portion size occurring both in laboratory (Haynes et al., 2020; Rolls et al., 2002) and real-world settings (French et al., 2014; Gough et al., 2021), and being sustained over the course of several days (Rolls et al., 2007).

Previous research has demonstrated that being served a smaller portion of food results in lower daily energy intake, even when participants are given additional eating opportunities to compensate for the calories consumed (Haynes et al., 2020), suggesting that reducing the size of food portions may be an effective intervention to reduce energy intake and promote weight loss. Indeed, findings have demonstrated smaller increases in weight when served smaller portion sizes compared with larger portion sizes (Jeffery et al., 2007; Kelly et al., 2009; Robinson et al., 2023).

The degree of later compensatory eating which occurs when being served a smaller (versus larger) portion of food appears to only be partial (Robinson et al., 2023) – this recent meta-analysis found that being served a smaller portion size resulted in lower energy intake of a meal. Furthermore, across pooled studies, participants compensated for 42 % of this reduced meal energy intake across the course of the rest of the day (i.e., by eating more later), but considerable variability in the degree of compensation was identified across studies (Robinson et al., 2023). One factor which was shown to potentially moderate the effect of portion size manipulation on daily energy intake was whether the comparison being made was between a large vs intermediate portion, or a relatively small vs intermediate portion size. Findings showed that the difference in daily energy intake between portion sizes was greater for studies comparing smaller vs intermediate portion sizes. This may be explained by physiological constraints of stomach capacity limiting additional

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intake when served a large portion size and suggests that the initial portion size of a meal may be important when considering the likely impact of portion size reduction on daily energy intake. Another factor which may affect the degree of compensation is the magnitude of the portion size reduction. From the studies included in Robinson et al.'s meta-analysis, the magnitude of portion size reduction between studies ranged from 20 % - 74 %. It is plausible to expect larger reductions in portion size to be met with conscious compensation, simply because the size of the reduction will elicit a noticeable difference between the size of what is being served and the size that one typically consumes from (Haynes et al., 2019; Shahrokni et al., 2022). Conversely, smaller reductions may not be met with conscious compensation, because an individual may not be aware that portion size has been reduced. One study demonstrated that selection of an alternative brand of chocolate (over a favourite chocolate brand) was made only when the portion size reduction of the favourite brand reached 22.6 %, suggesting that portion size reductions below 20 % may not invite consumer resistance because they are not noticeable (Shahrokni et al., 2022). Taken together, the extent to which consumers are aware of portion size reductions may be an important factor determining whether effect portion size reductions increase later compensatory eating.

The extent to which portion size reductions affect compensatory eating is important from a public health perspective because governmental interventions and programmes may aim for more modest reductions to portion size when altering the calorie content of meals, as opposed to very large reductions in portion size (e.g., greater than 50 %) typically studied in research (French et al., 2014; Gray et al., 2002). For example, in the UK, the governmental 'calorie reduction programme' has challenged the eating out of home, takeaway, and delivery sector to reduce calories by up to 20 %, by 2024 (Commons, 2023). Previous research investigating relatively small sized reductions to portion size is limited (Lewis et al., 2015). This warrants further investigation of the effect that smaller reductions of portion size (e.g., a reduction of 15 %) have on subsequent energy intake, as this level of reduction may better represent public health policy driven changes to portion size in real-world settings.

Appetite control and energy intake (including compensatory eating behaviours) are known to be driven partly by cognitive factors (Higgs & Spetter, 2018). For example, information presented on food products (such as food labelling) affects consumption behaviour (Shangguan et al., 2019) including food intake (Shide & Rolls, 1995). Episodic memory of a recently consumed meal can also affect appetite (Brunstrom, 2014). In one study by Brunstrom et al. (2012), hunger 2–3 h after consumption of a fixed portion of soup was governed by the amount of soup participants were told to have consumed, rather than the actual amount that they had consumed. To date, no studies have investigated how manipulating awareness of changes in portion size, can affect subsequent energy intake. Immediate energy compensation may be determined by the actual amount of energy served (regardless of one's psychological awareness of portion size changes) in part due to short-term regulation of energy intake being determined by signals relating to the relative emptiness of the gut (Rogers & Brunstrom, 2016). Whereas energy compensation which occurs after a period of time (e.g., 2–3 h after being served a reduced portion size), may be influenced by one's episodic memory of a meal (i.e., whether or not they remember the meal to have been reduced) (Higgs, 2015). These theoretical considerations suggest that compensatory eating in response to portion size reductions may differ dependent on when compensatory eating can occur and whether consumers are aware of portion size reductions. To address this, the present study aimed to investigate whether reducing portion size of a lunch meal (and awareness of this reduction) leads to lower subsequent energy intake – both immediately after the meal and also intake later in the day.

In the present study, participants attended two test days where they consumed a lunch meal (main course and desserts) and a dinner meal (main course and desserts). Participant's portion size of the lunch main course was manipulated on the second test day, such that participants were served either the amount of food that they had consumed on the first test day (control condition) or were served 15 % less – one group of participants who were served 15 % less were told that they had been served less than what they had previously consumed (reduced aware condition), whereas another group who were served 15 % less, were told that they had been served the amount that they had previously consumed (reduced unaware condition). A reduction of 15 % was examined as it would better represent public health policy driven changes to portion size in real-world settings. The primary outcome measures were: immediate energy intake (lunch desserts), total later energy intake (all energy consumed after the lunch main course and desserts), total post-pasta energy intake (all energy consumed after the lunch main course). We hypothesised that immediate energy intake would be greater in both portion size reduction conditions, compared with the control condition due to having consumed a smaller volume of energy. We also hypothesised that later energy intake would be greater in the reduced aware condition compared to the reduced unaware and the control condition due to participants being made aware that their lunch meal has been reduced and may later consciously (i.e. cognitive control of eating) compensate for the portion size reduction.

## 2. Methods

### 2.1. Design

The study used a mixed design with a within-subjects independent variable of session (baseline, experimental) and a between-subjects independent variable of condition (control, reduced aware, reduced unaware). In the baseline session, participants were given ad libitum access to a lunch meal (main course followed by desserts), and ad libitum access to a dinner meal (main course followed by desserts). For the experimental session, participants were randomly allocated to one of three conditions: *Control condition:* The portion size of the lunch meal was *the same* as the amount they had consumed in the baseline session. Participants were told that the amount served was the same amount as which they consumed in the previous session. *Reduced aware condition:* The portion size of the lunch meal was *15 % less* than the amount they had consumed in the baseline session. Participants were told that the amount served was *less than* what they had consumed in the previous session. *Reduced unaware condition:* As the reduced aware condition, but participants were told that the amount served was *the same* amount as which they consumed in the previous session. In the reduced aware condition only, a 15 % segment of the pasta meal was removed from the plate to create a visible gap on the plate (see supplementary materials). A washout period of at least one week was implemented between the two sessions. Participants were randomly allocated to their condition, sequenced using the RAND formula on Excel. Condition allocation was concealed from the researchers until the participant had passed the screening, as randomisation and concealment was conducted by a researcher not involved in the study.

### 2.2. Participants

Participants were recruited through online advertisement (i.e., social media), a participant database and word-of-mouth between October 2023 and May 2024. Our target sample size was based on a power calculation which determined the adequate number of participants for sufficient power given a session x condition interaction effect for the primary outcome measures. Previous studies have found the effect of portion size manipulation on later energy intake to be small-to-moderate (SMD = 0.369) (Robinson et al., 2023). As we anticipated any effect in the present study to be smaller due to the magnitude of portion size reduction being smaller than in previous studies, we powered the study to be able to detect a small effect. Therefore, we powered for a within-between subject's interaction effect of $f = 0.11$, using an alpha level of

$p < .05$, 80 % power, and a within-subjects correlation of 0.75 (a conservative estimate based on Langfield et al. (2023) who found a correlation of $r = 0.84$ of food intake across portion sizes), resulting in a required $N = 105$. We aimed to recruit a minimum $N = 108$ to allow for an equal number of participants based on recruitment strata. Recruitment was stratified by sex, education level (recruiting no more than 60 % of the sample whose highest qualification was level 4 - equivalent to the first year of a bachelor's degree - or above), and student status with no more than 10 % of the sample being current students. These numbers were chosen in order to avoid having an unrepresentative sample which was heavily biased towards individuals with higher education levels or current students. Eligibility criteria were: UK resident and aged 18–60 years, BMI between 18.5 and 32.5 kg/m$^2$ (this range chosen because it is representative of the population of England, as more than 70 % of the population fall within this range (NHS, 2022)), proficient in English language, self-reported willingness to eat the test foods. Exclusion criteria were: currently using medication which affects appetite, pregnancy, current or previous diagnosed eating disorder, currently dieting, food allergies or intolerances, vegan (due to test foods used). The study was approved by the University of Liverpool Institute of Psychology, Health and Society Research Ethics Committee (ethics reference number: 6154). The study methodology and analysis plan were pre-registered on the Open Science Framework https://osf.io/c3gaj/. The study was also registered at www.clinicaltrials.gov as NCT06119295.

See supplementary materials for CONSORT flowchart for participant enrolment, allocation, and analysis.

### 2.3. Procedure

Sessions were completed in a laboratory setting at the University of Liverpool. Participants attended the lab to complete a screening session where informed consent was given by the participant, along with inclusion criteria checks, completion of the demographic measures, and height and weight measurements. All participants attended lunch between 12:30–14:00 and dinner between 16:30–18:00. Lunch and dinner were scheduled to be four hours apart for all participants. Participants were asked to abstain from eating for at least 2 h prior to the lunch session, to keep exercise levels consistent across sessions, and to avoid consuming alcohol on both test days. In the baseline lunch session participants first completed hunger and fullness ratings, as well as mood ratings and a sleep questionnaire – these were included because the study used a cover story to mask the true aims, being described as investigating diet, mood, and sleep. Participants were then served the lunch main course (1200 g of pasta was presented in a bowl for the participant to freely serve onto a plate) and water (see Fig. 1 for a list of all test foods used), and then completed hunger and fullness ratings. Participants were then served the lunch desserts (presented in separate bowls, to be served onto a plate), followed by another set of mood, hunger and fullness ratings. Participants were given a snack box to take away with them to consume food from between meals, if desired. They were instructed to only consume foods from the snack box up until they went to sleep that night. Participants returned for dinner where they first completed mood, hunger, and fullness ratings, and were then served the dinner main course (each food was presented in a separate bowl, to be served onto a plate), then completed a new set of hunger and fullness ratings, were then served the dinner desserts, and were lastly asked to complete a final set of mood, hunger, and fullness ratings. Participants returned the next day to return their snack box, detailing what they consumed and when they consumed it (along with any additional intake beyond the snack box). After the washout period, participants returned for the experimental session. This was identical to the baseline session with the following differences: for the lunch, participants were told that due to being short on time and having a limited amount of pasta, they would be served a portion of pasta which was the amount that they consumed in the previous session (control condition and reduced unaware condition) or they were told that they would be served an amount of pasta less than what they consumed in the previous session (reduced aware condition only) – this food was served to participants on a plate.

**Baseline Session**

| Lunch Main Course (serving size for the baseline session only) | Portion (g) | Energy content (kcal) |
|---|---|---|
| Tomato and Mozzarella Pasta Bake | 1200 | 1656 |
| Water | 500 | 0 |

| | | |
|---|---|---|
| **Lunch Desserts** | | |
| Brownie Bites | 110 | 432 |
| Madeleine cakes | 125 | 558 |
| **Dinner Main Course** | | |
| Vegetable Chilli | 700 | 490 |
| Long Grain Rice | 600 | 816 |
| Water | 500 | 0 |
| Mixed Vegetables | 160 | 68 |
| Tortilla Chips | 60 | 282 |
| **Dinner Desserts** | | |
| Cornflake Clusters | 100 | 460 |
| Millionaire Shortbread bites | 120 | 720 |
| **Snack Box** | | |
| Apple (2) | 267 | 142 |
| Cereal Bar | 42 | 196 |
| Crisps (2 packs) | 50 | 270 |
| Mini Carrots | 100 | 42 |
| Biscuits (2 packs) | 44 | 210 |
| Dried fruit and nut mix | 25 | 133 |

**Experimental Session**

| Lunch Main Course Control Condition (values are average serving size for condition in the experimental session) | Portion (g) | Energy content (kcal) |
|---|---|---|
| Tomato and Mozzarella Pasta Bake | 434.70 | 599.89 |
| Water | 500 | 0 |

| Lunch Main Course Reduced Aware Condition (values are average serving size for condition in the experimental session) | Portion (g) | Energy content (kcal) |
|---|---|---|
| Tomato and Mozzarella Pasta Bake | 350.14 | 483.19 |
| Water | 500 | 0 |

| Lunch Main Course Reduced Unaware Condition (values are average serving size for condition in the experimental session) | Portion (g) | Energy content (kcal) |
|---|---|---|
| Tomato and Mozzarella Pasta Bake | 398.61 | 550.08 |
| Water | 500 | 0 |

| | | |
|---|---|---|
| **Lunch Desserts** | | |
| Brownie Bites | 110 | 432 |
| Madeleine cakes | 125 | 558 |
| **Dinner Main Meal** | | |
| Vegetable Chilli | 700 | 490 |
| Long Grain Rice | 600 | 816 |
| Water | 500 | 0 |
| Mixed Vegetables | 160 | 68 |
| Tortilla Chips | 60 | 282 |
| **Dinner Desserts** | | |
| Cornflake Clusters | 100 | 460 |
| Millionaire Shortbread bites | 120 | 720 |
| **Snack Box** | | |
| Apple (2) | 267 | 142 |
| Cereal Bar | 42 | 196 |
| Crisps (2 packs) | 50 | 270 |
| Mini Carrots | 100 | 42 |
| Biscuits (2 packs) | 44 | 210 |
| Dried fruit and nut mix | 25 | 133 |

**Fig. 1.** Portion sizes of all foods served (grams and energy content presented) for baseline session (left-hand side) and experimental session (right-hand side).

The amount served to participants on the plate was calculated based on the amount of pasta consumed in the baseline session. See supplementary materials for further details and example images of how the pasta was served. The only other difference between the baseline session and the experimental session was that when participants returned their snack box the next day, they completed additional questionnaires (compensatory health belief scale, Dutch Eating Behaviour Questionnaire (DEBQ), end-of-study measures), and were fully debriefed. Participants were reimbursed £70 for their time.

### 2.4. Measures

#### 2.4.1. Energy intake measures

All foods were weighed before and after being served, in order to calculate how much food had been consumed. The weight of food was converted into kilocalories (kcal) by multiplying the amount of food consumed by the energy density (kcal/g) based on manufacturer's information. Any food or drink consumed beyond what was provided to participants (referred to as additional energy intake), was recorded and entered onto a digital diet tracking tool: MyFitnessPal, where this energy intake was converted into kcal. MyFitnessPal has been shown to be accurate for calorie estimation (Evenepoel et al., 2020). For the test foods, we used the following measures:

*Immediate energy intake*: Energy consumed immediately after the pasta meal (lunch dessert intake).

*Later energy intake*: Energy consumed after the lunch meal for the rest of the day (snack box, dinner meal, dinner dessert, self-reported additional energy intake).

*Post-pasta energy intake*: Energy consumed after the fixed-portion of the pasta meal for the rest of the day (lunch dessert, snack box, dinner meal, dinner dessert, additional energy intake).

*Total energy intake*: Energy consumed from the pasta meal and from that point onwards for the rest of the day.

#### 2.4.2. Questionnaire measures

*Hunger and fullness:* Participants rated current levels of hunger and fullness on visual analogue scales scored from 0 (Not at all) to 100 (Extremely).

*Demographic measures:* Participants reported their age, sex, ethnicity, highest educational qualification, and equivalised household income (household income adjusted for household size – see supplementary materials for an explanation of how this is calculated and for frequency counts of ethnicity, and highest educational qualification).

**Table 2**
Participant characteristics by condition – means and standard deviations or frequency counts.

| | Control (N = 36) | Reduced Aware (N = 36) | Reduced Unaware (N = 38) | Total Sample (N = 110) |
|---|---|---|---|---|
| Age (years) | 39.97 ± 12.89 | 37.19 ± 12.93 | 35.71 ± 12.62 | 37.59 ± 12.82 |
| Sex (Male: Female) | 18:18 | 16:20 | 18:20 | 52:58 |
| BMI (kg/m$^2$) | 26.00 ± 3.59 | 25.94 ± 3.33 | 25.23 ± 3.96 | 25.71 ± 3.63 |
| Equivalised household income (GBP) | £21,216.67 ± 9985.55 | £23,528.10 ± 12,992.01 | £21,237.34 ± 11,663.54[a] | £21,987.09 ± 11,556.08 |
| Dietary restraint (out of 5) | 2.51 ± 0.92 | 2.71 ± 0.69 | 2.45 ± 0.71 | 2.56 ± 0.78 |
| Compensatory Health Beliefs (out of 20) | 11.06 ± 4.14 | 11.19 ± 3.43 | 10.63 ± 3.20 | 10.95 ± 3.58 |

[a] Data missing from one participant.

#### 2.4.3. End-of-study measures

*Dietary restraint:* Participants completed the DEBQ restraint subscale (Van Strien et al., 1986). This subscale consists of 10 items which measure concerns of dietary restraint (e.g., "Do you watch exactly what you eat?"). Items are scored from 1 (Never) to 5 (Very often) Present study: $\omega_t = 0.93$.

*Compensatory health beliefs:* Participants completed the portion size subscale of the Diet-related Compensatory Health Beliefs Scale (Poelman et al., 2013). This requires participants to rate from 1 (Not at all) to 5 (Very much) how much each of the beliefs stated match their own beliefs about portion size (e.g., "If I eat a small meal, it's fine to have a larger portion during the next meal"). Present study: $\omega_t = 0.81$.

*Aims guessing:* Using an open-ended format, participants were asked what they believed the aims of the study were. Responses were independently coded by two researchers as being either aware or unaware of the aims. Any disagreements between researchers was resolved by a third researcher.

*Manipulation check:* participants were asked 'Was the lunch portion size of tomato and mozzarella pasta you consumed, smaller, larger, or the same as the lunch portion size of tomato and mozzarella pasta you consumed in the previous session?' See supplementary materials for results.

*Food liking and familiarity ratings:* Participants were asked to rate how much they liked each of the foods presented in the study, scored from 1 (Not at all) to 7 (Very much) and were asked to indicate how familiar they are with the test foods served in the study: "I would normally eat this type of food", scored from 1 (Strongly Disagree) to 7 (Strongly Agree). See supplementary materials for results.

### 2.5. Data analysis

#### 2.5.1. Primary analyses

*2.5.1.1. Energy intake.* Mixed 2 x (session: baseline, experimental) x 3 (condition: control, reduced aware, reduced unaware) ANOVAs were conducted on energy intake outcomes. Additionally, we computed Bayes factors in order to determine the level of support for the null model vs. the following mixed ANOVA models measuring immediate energy intake (lunch dessert), later energy intake, and post-pasta energy intake: condition (control, reduced aware, reduced unaware), session (baseline, experimental), condition + session + condition x session. Default priors were used: ($r$ scale fixed effects = 0.5; $r$ scale random effects = 1; $r$ scale covariates = 0.354). We report $BF_{01}$ which provides indication of support for the null hypothesis. Standard cut-offs used were: 1–3 = anecdotal evidence; 3–10 = moderate evidence; 10–30 = strong evidence; 30–100 = very strong evidence; > 100 = extreme evidence (Stefan et al., 2019). For instance, $BF_{01} = 5$ indicates the data are five times more likely under the null compared to the alternative hypothesis.

*2.5.1.2. Non-pre-registered analysis.* In error, we did not pre-register analyses to determine the effect of the portion size reduction of pasta on pasta energy intake. To confirm the portion size manipulation led to a greater reduction in pasta intake between the baseline and experimental sessions in the reduced portion size conditions, compared to the control condition, an additional 2 x (session: baseline, experimental) x 3 (condition: control, reduced aware, reduced unaware) mixed ANOVA was conducted on pasta energy intake.

*2.5.1.3. Sensitivity analyses.* Sensitivity analyses were conducted to examine whether the pattern of results from the primary analyses differed after 1) excluding participants who correctly guessed the aims of the study, 2) excluding outliers on main outcome variables (identified as those with a value >2.5 the median absolute deviation (MAD) value from condition median (Leys et al., 2013) and 3) excluding influential cases (identified as those with a Cook's distance >1 (Stevens, 1984)).

*2.5.2. Secondary analyses*

*2.5.2.1. Moderation effects.* We performed a pre-registered moderation analysis to investigate whether scores on the compensatory health beliefs scale moderated the effect of condition on total energy intake. Compensatory health belief scores were mean centred prior to the analysis (see supplementary materials for results).

*2.5.2.2. Further intake analyses.* We performed additional 2 x (session: baseline, experimental) x 3 (condition: control, reduced aware, reduced unaware) mixed ANOVAs on post-lunch snack box intake (snack box intake consumed in the break between lunch and dinner) and also dinner main course intake.

*2.5.2.3. Hunger and fullness.* To investigate the effect of condition on hunger and fullness ratings during the experimental session, two 2 (time: lunch pre-meal, lunch post-meal) x 3 (condition: control, reduced aware, reduced unaware) mixed ANOVAs were conducted.

## 3. Results

In total, 114 participants started the study, but 4 were lost to attrition after the baseline session, resulting in an $N = 110$ for all analyses. See Table 2 for details of participant characteristics.

Pasta energy intake (Table 3).

The analysis of session and condition on pasta energy intake revealed a nonsignificant main effect of condition $F(2,107) = 1.44$, $p = .242$, $\eta p^2 = 0.026$ and a significant main effect of session: $F(1,107) = 261.48$, $p < .001$, $\eta p^2 = 0.710$, whereby pasta intake was greater in the baseline session (mean = 605.93 kcal, SD = 211.04) than in the experimental session (mean = 490.78 kcal, SD = 189.10, d = 1.47). Findings also revealed a significant session x condition interaction $F(2,107) = 6.975$, $p = .001$, $\eta p^2 = 0.115$. Breaking down this interaction, paired-samples *t*-tests revealed that pasta intake was greater in the baseline session than in the experimental session in the control condition $t(35) = 5.24$, $p < .001$, d = 0.87, reduced aware condition $t(35) = 14.43$, $p < .001$, d = 2.40, and the reduced unaware condition $t(37) = 11.13$, $p < .001$, d = 1.81. As expected this difference was greatest in the two reduced portion size conditions vs. control.

### 3.1. Primary analyses

Immediate energy intake (Table 3).

There was a significant main effect of session $F(1,107) = 5.14$, $p = .025$, $\eta p^2 = 0.046$, whereby immediate intake after the lunch main course was greater in the experimental session (mean = 357.04 kcal, SD = 206.23) compared with the baseline session (mean = 330.97 kcal, SD = 162.63, d = −0.21). There was a non-significant main effect of condition $F(2,107) = 0.318$, $p = .729$, $\eta p^2 = 0.006$, and a non-significant session x condition interaction $F(2,107) = 0.948$, $p = .391$, $\eta p^2 = 0.017$. Bayes factors did not provide support for the null for the main effect of session ($BF_{01} = 0.684$), but did provide support for the null for the main effect of condition ($BF_{01} = 3.447$) and for the session x condition interaction ($BF_{01} = 11.694$).

Later energy intake (Table 3).

The analysis of later energy intake revealed a non-significant main effect of session $F(1,107) = 0.661$, $p = .418$, $\eta p^2 = 0.006$, a non-significant main effect of condition $F(2,107) = 0.151$, $p = .860$, $\eta p^2 = 0.003$, and a non-significant session x condition interaction $F(2,107) = 0.560$, $p = .573$, $\eta p^2 = 0.010$. Bayes factors provided support for the null for the main effect of session ($BF_{01} = 5.101$), the main effect of condition ($BF_{01} = 4.368$), and for the session x condition interaction ($BF_{01} = 164.412$).

Post-pasta energy intake (Table 3).

The analysis for total post-pasta energy intake revealed a non-significant main effect of session $F(1,107) = 0.005$, $p = .943$, $\eta p^2 < 0.001$. The main effect of condition was non-significant $F(2,107) = 0.225$, $p = .799$, $\eta p^2 = 0.004$, and the session x condition interaction was also non-significant $F(2,107) = 0.481$, $p = .620$, $\eta p^2 = 0.009$. Bayes factors provided support for the null for the main effect of session ($BF_{01} = 6.840$), for the null for the main effect of condition ($BF_{01} = 3.547$) and for the session x condition interaction ($BF_{01} = 193.818$).

Sensitivity analysis.

Five participants guessed the aims of the study. Their removal did not affect primary analysis results. Seven participants did not fully adhere to study instructions and their exclusion did not markedly affect primary analysis results. See supplementary materials for full details.

### 3.2. Secondary analyses

Hunger and fullness ratings.

ANOVAs on pre- and post-pasta hunger ratings revealed a significant main effect of time $F(1,107) = 357.167$, $p < .001$, $\eta p^2 = 0.769$, whereby hunger levels were greater pre-main course (mean = 69.74, SD = 19.42) compared with post-pasta (mean = 25.01, SD = 20.61, d = 1.81). There was a non-significant main effect of condition: $F(2,107) = 2.887$, $p = .060$, $\eta p^2 = 0.051$, and a non-significant time x condition interaction: $F(2,107) = 0.169$, $p = .845$, $\eta p^2 = 0.003$. For fullness ratings, there was a main effect of time: $F(1,107) = 374.00$, $p < .001$, $\eta p^2 = 0.778$, whereby fullness ratings were significantly greater after the pasta meal (mean = 67.60, SD = 21.15) compared with before the pasta meal (mean = 20.23, SD = 16.34, d = −1.86). There was a non-significant main effect of condition $F(2,107) = 0.366$, $p = .694$, $\eta p^2 = 0.007$, and a non-significant time x condition interaction $F(2,107) = 0.171$, $p = .843$, $\eta p^2 = 0.003$.

Additional secondary analyses.

There was no evidence of moderation by scores on the compensatory health belief scale. Analyses of post-lunch snack box intake and dinner main course intake produced the same results as in the primary analyses (no effects of condition or condition x session interactions). See supplementary materials for further details.

**Table 3**
Descriptive statistics of energy intake (kcal) - means and standard deviations.

| | Control ($n = 36$) | | Reduced Aware ($n = 36$) | | Reduced Unaware ($n = 38$) | |
|---|---|---|---|---|---|---|
| | Baseline | Experimental | Baseline | Experimental | Baseline | Experimental |
| Pasta energy intake | 599.89 ± 214.43 | 522.34 ± 204.67 | 568.46 ± 150.71 | 439.70 ± 132.99 | 647.15 ± 251.16 | 509.26 ± 212.42 |
| Immediate energy intake | 311.00 ± 164.00 | 346.92 ± 214.89 | 342.04 ± 167.69 | 381.52 ± 211.68 | 339.41 ± 159.05 | 343.44 ± 195.83 |
| Later energy intake | 1366.26 ± 450.31 | 1298.99 ± 504.38 | 1379.30 ± 404.38 | 1386.71 ± 496.88 | 1380.49 ± 395.26 | 1368.06 ± 409.17 |
| Post-pasta energy intake | 1677.26 ± 559.42 | 1645.91 ± 664.91 | 1721.35 ± 478.01 | 1768.23 ± 642.47 | 1719.90 ± 478.88 | 1711.50 ± 524.93 |
| Total energy intake | 2277.16 ± 708.52 | 2168.25 ± 788.68 | 2289.81 ± 558.40 | 2207.94 ± 701.95 | 2367.05 ± 646.88 | 2220.76 ± 631.96 |

Pasta energy intake = energy consumed during the lunch main course; Immediate energy intake = energy consumed immediately after the lunch main course (lunch desserts); Later energy intake = energy consumed after the lunch meal (snack box, dinner main course, dinner desserts, additional intake); Post-pasta energy intake = energy consumed after the lunch main course (lunch desserts, snack box, dinner main course, dinner desserts, additional intake); Total energy intake = energy consumed from the lunch main course, lunch desserts, snack box, dinner main course, dinner desserts, additional intake.

### 3.3. Non-pre-registered analyses

Given that we found the portion size manipulation decreased pasta energy intake, but found no evidence of greater subsequent energy intake in the portion size reduction conditions vs. control condition, we explored the overall effect on total energy intake (see Table 3 for data) and expected there to be larger decreases in total experimental session energy intake for the portion size reduction conditions vs. control. Using ANOVA, there was a non-significant main effect of condition $F(2,107) = 0.114$, $p = .892$, $\eta p^2 = 0.002$, but a significant main effect of session: $F(1,107) = 9.865$, $p = .002$, $\eta p^2 = 0.084$, whereby total intake was greater in the baseline session (mean = 2312.35, SD = 636.38) than in the experimental session (mean = 2199.38, SD = 702.87, d = 0.30). However, the session x condition interaction was non-significant $F(2,107) = 0.276$, $p = .760$, $\eta p^2 = 0.005$. Yet, Bayes factors provided only anecdotal support for the null for the interaction effect ($BF_{01} = 2.138$). Examining data expressed as change in total energy intake between sessions (see Table 4 and Fig. 2 for graphical representation), participants in the control condition reduced their energy intake between sessions on average by 109 kcals. Consistent with minimal evidence of compensation, participants in the reduced unaware portion size condition reduced their total session energy intakes by a directionally larger 146 kcals. However, compared to participants in the control condition, participants in the reduced aware condition displayed a reduction in total energy intake between sessions (82 kcals) that was unexpectedly directionally smaller than the control condition and markedly smaller than the reduced unaware condition. Consistent with this, expressed as a % of each participant's baseline session total energy intake, the reduced aware condition only decreased their energy intake between sessions by 4.1 %, compared to the control condition (5.1 %) and reduced unaware condition (5.7 %). For means and standard deviations, see Table 4.

Pasta intake difference (kcal) = experimental session pasta intake – baseline session pasta intake; Pasta intake difference score (%) = [(experimental session pasta intake – baseline Session pasta intake)/(baseline session pasta intake)]*100; Total energy intake difference (kcal) = experimental session total intake – baseline session total intake; Total energy intake difference score (%) = [(experimental session total intake – baseline session total intake)/(baseline session total intake)]*100.

## 4. Discussion

The present study investigated whether a portion size reduction of 15 % for a lunch main course affected subsequent energy intake and whether participant awareness of the reduction increased later compensatory eating. Although the 15 % portion size reduction decreased lunch main course energy intake, we found no statistically significant evidence that immediate and later energy intake differed between portion size reduction conditions and the control condition, as shown by nonsignificant session by condition interaction effects for immediate and later energy intake outcomes and Bayes factors in support of null hypotheses. However, in non-pre-registered analyses examining total energy intake measured during session days (including portion size reduced meals) we did not find convincing evidence that total energy intake over the course of the day was markedly lower for portion size reduction conditions and this was particularly the case for the portion size reduction condition in which participants were made aware of the reduction. We therefore propose that although the present study provides some suggestion that when portion size reductions are made without consumer awareness, later compensatory eating appears relatively minimal, our findings may be less conclusive for when consumers are aware of portion size reductions.

We predicted that energy intake consumed after the lunch meal would be greater in the reduced aware condition due to these participants being explicitly told that they had been served a portion size less than what they had previously consumed, resulting in the episodic memory of undereating and this in turn potentially facilitating later compensatory eating, as previous research has demonstrated that episodic memory of a meal can influence appetite (Brunstrom, 2014; Brunstrom et al., 2012). Primary analyses did not show convincing evidence in support of this hypothesis. However, this may be explained by participants using their episodic memory of the overall lunch meal (i.e., pasta and dessert), to determine later energy intake, as opposed to remembering only the reduced portion size of pasta.

Previous findings have demonstrated that being served a reduced portion size of food does not result in full compensation of energy intake, with only 42 % of the reduced energy intake being compensated for at a later point on the same day (Robinson et al., 2023). The present study failed to show any clear evidence of compensation immediately after the portion size reduction or when measured later in the day. However, there was no effect of portion size reductions on total energy intake across the study day in which portion size was manipulated. Descriptive statistics suggested that participants in the reduced aware condition may have potentially displayed some level of compensatory energy intake across the course of the study day. We presume this could have occurred to some participants consciously increasing their food intake across later eating occasions. However, this proposal will require formal testing and further supporting evidence as results of planned inferential statistical analysis was not consistent with this observation.

Although our study was reasonably well powered to detect immediate compensatory effects on energy intake in response to a portion size reduction, some participants may have consumed a small amount of additional energy consistently across post-portion size reduction eating occasions (resulting in no change to overall session energy intake) and we lacked the statistical power to detect these changes. This is plausible, particularly due to the number of calories that participants had available to them after consumption of the lunch main meal for the remainder of the day (in excess of 4800 cal). We implemented this large upper limit of calorie intake to minimise the chance of ceiling effects occurring on later energy intake. However, future research may wish to consider using an amount of food which would not encourage high energy intake and reduce inter-participant variability in energy intake, therefore increasing sensitivity for detecting changes in overall energy intake caused by the portion size manipulations. As the analyses showing a lack of effect on total energy intake were unplanned and this lack of effect on total energy intake may be due to variability and random error in energy intake between participants, caution should be applied when interpreting this suggestion. Nonetheless, we propose that this now warrants formal testing using studies better equipped to examine these suggestions.

Many previous studies have used larger changes in portion size serving compared to the reduction used in the present study, however one previous study has used a comparable portion size reduction (Lewis et al., 2015). In this study by Lewis et al. (2015), reducing a breakfast meal portion size by 20 % did not result in change to lunch or daily energy intake, relative to a control, however a separate 40 % reduction condition produced a significant reduction in daily energy intake, compared to the 20 % reduction and control conditions. Of note, the present study revealed that the portion size manipulation did not

**Table 4**
Descriptive statistics of difference scores - means and standard deviations.

| | Control ($n$ = 36) | Reduced Aware (n = 36) | Reduced Unaware ($n$ = 38) |
|---|---|---|---|
| Pasta intake difference (kcal) | −77.56 ± 88.78 | −128.76 ± 53.56 | −137.89 ± 76.40 |
| Pasta intake difference score (%) | −13.08 ± 14.25 | −23.17 ± 8.50 | −21.79 ± 9.68 |
| Total energy intake difference (kcal) | −108.91 ± 378.24 | −81.88 ± 404.20 | −146.28 ± 341.94 |
| Total energy intake difference score (%) | −5.19 ± 19.53 | −4.14 ± 17.38 | −5.57 ± 14.60 |

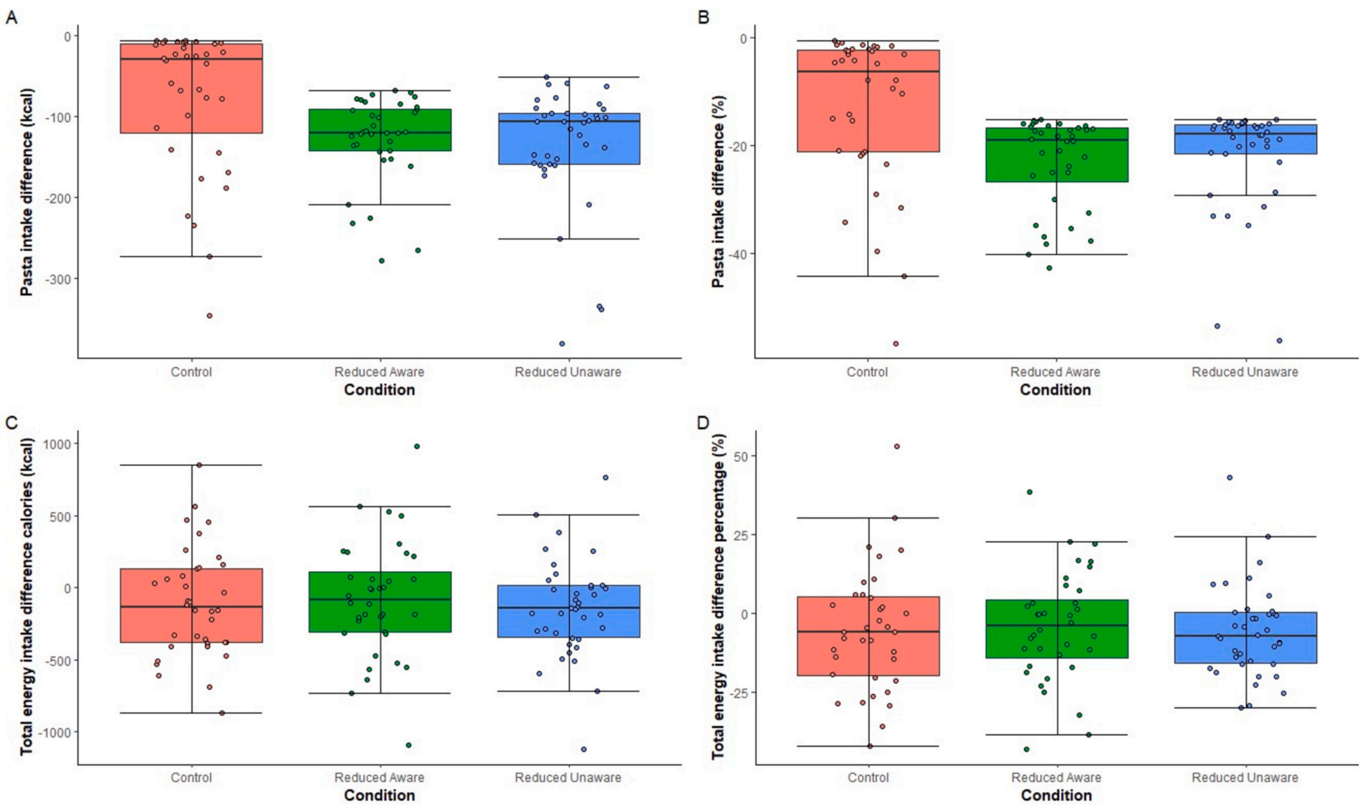


**Fig. 2.** Boxplots illustrating difference scores split across each measure, separately for caloric difference and percentage difference. A = Pasta (lunch main course) difference intake (kcal): experimental session pasta intake – baseline session pasta intake. B = Pasta difference intake (%): [(experimental session pasta intake – baseline Session pasta intake)/(baseline session pasta intake)]*100. C = Total energy (kcal): experimental session total intake – baseline session total intake. D = Total energy intake difference (%): [(experimental session total intake – baseline session total intake)/(baseline session total intake)]*100.

significantly affect pre- and post-pasta hunger and fullness ratings. The portion size reduction of 15 % in the present study may therefore not have been large enough to significantly affect feelings of hunger and fullness, which may partly explain why there was no difference in immediate energy intake across conditions (Rogers & Brunstrom, 2016). This is consistent with the previous findings of Lewis et al. (2015) who did not show a change in post-consumption hunger or fullness ratings between the control condition and the 20 % reduced portion size condition, but did in the 40 % reduction portion size condition. Collectively, these findings suggest that physiologically driven compensatory eating responses may only occur for larger reductions of portion size (i.e. > 20 %).

Based on these findings, reducing portion size of meals by up to 15 % may be an effective strategy to reduce energy intake, assuming consumers are not made explicitly aware. Such a 'stealth' approach to portion size reduction (a gradual reduction of portion sizes of which individuals are not explicitly made aware of) has been previously suggested as a potential intervention focused on portion sizes (Vermeer et al., 2014). This may be an approach which would lead to a reduction in energy intake without conscious compensation in the real world.

This study has a number of strengths. Firstly, by implementing a baseline session, we ensured that the pasta portion size served in the experimental session was standardised to each participants' appetite and the use of a cover story reduced potential effects of demand characteristics (Kersbergen et al., 2019; Robinson et al., 2014). There are some limitations of the present study. Later compensation eating was measured in meals using a range of different foods - this choice of food may have stimulated intake through sensory-specific satiety (Rolls et al., 1981), as opposed to examining subsequent intake using the portion size reduced food only. As discussed, although conservatively powered based on a meta-analysis of previous portion size studies, our study was not well powered to detect very small differences in energy intake (e.g., < 5 %) between experimental conditions. A minor limitation is that a small number of participants were excluded from analyses (due to non-compliance and attrition), however sensitivity analyses suggests that results remained unchanged with and without these participants included therefore it is unlikely that removal of these participants introduced bias to our study findings. Additionally, questions remain about the generalisability of the study findings to the real-world, given that eating patterns related to portion size have been suggested to be greater in the real-world than in laboratory settings (Gough et al., 2021). Lastly, physical activity levels during each test day were not measured. Given that portion size reductions were small, we assume that a form biological correction to energy expenditure would be highly unlikely. However, we cannot rule out that some compensation in the form of energy expenditure could have occurred and our study was not designed to test this.

## 5. Conclusions

The present study investigated whether reducing the portion size of a lunch main course by 15 % affected subsequent energy intake. Findings suggest that this reduction in portion size decreases energy intake of that course and may not invite subsequent compensatory eating. However, further research is required to understand the size of portion reductions to promote reduced daily energy intake and if this is affected by awareness of portion size reductions.

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## Contribution

The authors' responsibilities were as follows: TG, ER, JB, AF, and AJ designed the research. TG and JB collected the data, TG analysed the data. TG and ER wrote the paper and had primary responsibility for final content and all authors have read and approved the final manuscript.

## Ethical Statement

The study was approved by the University of Liverpool Institute of Psychology, Health and Society Research Ethics Committee (ethics reference number: 6154).

## CRediT authorship contribution statement

**Thomas Gough:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Jane Brealey:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Amy Finlay:** Writing – review & editing, Conceptualization. **Andrew Jones:** Writing – review & editing, Conceptualization. **Eric Robinson:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2025.105443.

## Data availability

The dataset supporting the conclusions of this article is available in the Open Science Framework repository https://osf.io/c3gaj/.

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