

Title: The Impact of Food Reformulation on Energy Intake

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Description: A study examining the influence of altering energy density on acute consumption and later compensation.

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Subjects: Psychology, Life Sciences, Health Psychology

Background:

Food prepared outside of the home tends to have a high energy content, and high levels of nutrients of concern (sodium, fat, saturated fat and sugar)(1), especially when compared to home-cooked food(2). Over time, food prepared outside of the home has become increasingly accessible and convenient, particularly since the start of the coronavirus pandemic(3, 4) where the use of food delivery services increased substantially. It is anticipated that a population-level approach would be most beneficial to combat the impact of these changes on diet and health(5). This has prompted policies enforcing reformulation, for example the soft-drinks industry levy (SDIL) and the salt reduction programme have both seen success in the UK in reducing intake of sugar and salt in the population, and perhaps more importantly, encouraging the food industry to provide healthier alternatives(6, 7). More recently proposed in the UK is the calorie reduction programme which challenges the food industry to achieve a 20% reduction in calories by 2024(5), with specific recommendations for food categories, and the out-of-home sector. A key benefit of this programme is that little burden is placed on the public to make healthy choices, as the foods consumed every day will become healthier, with little need for individuals to review and sustain changes(5).

Energy density is defined as “the energy content per unit weight of food”(8) and is measured as kilocalories per gram (kcal/g). Foods with a low energy density tend to have a high water content (i.e. fruits and vegetables), and foods with high energy density are typically ultra-processed, with higher fat, carbohydrate and sugar content(9). Together, the water and fat content of a food account for 99% of the variance in energy density(9). A diet characterised as higher energy density is associated with higher total energy intake(10, 11) and relationships have been identified in both adults and children between higher dietary energy density and heavier body weight(12). Humans evolved consuming low energy dense foods (<1.75kcal/g) so it is unclear whether we have adapted to differentiate sufficiently, and therefore compensate for, the high energy density foods present in the modern diet(13).

A number of studies suggest that when energy density of a food is manipulated it has a linear effect on energy intake, because consumers tend to eat a constant weight of food(14). This evidence comes from studies that have measured the impact of covert manipulations of energy density on food intake. For example in the US, an older group of participants who relied on home delivered meals were given regular (1.1kcal/g) or enhanced (2.2kcal/g) meals(15). When the enhanced meal was provided, kcal intake at lunch increased by 86% and there was an average increase in 453kcal over 24 hours. In another study, healthy males were given a lunch of noodle soup at one of five different levels of energy density (ranging from 0.27kcal/g to 1.81 kcal/g)(16). Total daily energy intake differed significantly between conditions, and this was directly associated with intake at lunch time; there was no evidence of participants adjusting their lunch time energy intake based on the energy density of the meal or compensating for increases in energy intake at subsequent meals.

A limitation of existing research is that it tended to examine the effects of manipulating energy density for relatively low energy dense foods and foods are manipulated covertly during a single session, so consumers are not able to learn about the energy content(14). For example, in the two studies mentioned, the highest energy densities tested were 1.8kcal/g(16) and 2.2kcal/g(15) respectively. However, consumers often are exposed to and consume foods of higher energy density. In one UK fast food restaurant menu, main meal items ranged from 1.9kcal/g to 3.2 kcal/g(17). This may be an important consideration because recent observational research suggested that up to approximately 1.5-2kcal/g, individuals are relatively insensitive to changes in energy density, and there is no indication of compensation through altering meal size(18). However, upwards of approximately 1.5-2kcal/g, the authors proposed that individuals compensate for increases in energy density by selecting and consuming smaller meal sizes. The proposed explanation for this is that individuals rely on the volume of food as the dominant signal with energy dilute foods (i.e.<1.5) and rely on calorie content as the dominant signal for energy rich foods(18). The volume signal is related to gastric distention and the calorie content signal is related to both learned and unlearned effects. If correct, the proposed model has implications for food product energy reformulation, as it suggests that reducing the energy density of more energy dense food products (e.g. >2.5kcal/g to 2kcal/g) may not lead to reductions in energy intake because within this range of energy densities consumers adjust meal size to compensate for changes in energy density.

However, there has been no formal testing of the proposed model using experimental approaches and it is unclear how efficiently consumers learn about the density of energy dense foods and adjust their meal size accordingly. In a previous study, we tested whether consumers adjust the meal size when given foods varying in energy density. This previous study measured the meal size of three desserts that were familiar to participants with the same basic ingredients (vanilla yoghurt, vanilla ice cream, vanilla cheesecake) but varying in energy densities (1.2kcal/g, 1.9kcal/g, 3.5kcal/g), with the aim of understanding the extent to which learned energy density would influence intake.

We aim to follow up on this previous study, by covertly manipulating the level of energy density of a meal, using the same parameters as the prior study. In this previous study the foods provided were noticeably different to participants, and so underlying preferences and differences in sensory and nutritional aspects of the meals may have influenced the amount consumed. Equally, this study did not measure whether later intake differed following consumption of desserts varying in energy density. For the present study, the foods provided will be variations on the same meal (loaded fries), so participant's expectations of the meals should be comparable. This will help us to understand whether reformulation to approximately 2kcal/g would lead to a reduction in energy intake, or if further reduction, below 1.5kcal/g is required to influence immediate eating behaviour positively by reducing energy intake. Additionally, if there are significant effects of energy density, it is vital to determine whether these changes are compensated for by consumers later on in the day.

Primary objectives: To observe differences in consumption (g/kcal) when participants are given a meal covertly manipulated to be low, medium or high in energy density.

Secondary objective: To measure later food intake, in order to observe any evidence of later compensation in response to experimental condition.

To measure intake over the full day, in order to understand whether one manipulated meal impacts daily energy intake.

Study Information

Hypotheses:

Based on Flynn et al(18), it is hypothesised that as the energy density of the lunch meal increases from low ED to medium ED, the amount of the lunch consumed (g) will remain similar, but due to the increased energy density, the calories consumed will increase.

As energy density of the lunch meal increases from medium ED to high ED, the amount of lunch consumed (g) will decrease, due to people compensating for the increase in energy density (i.e., participants will attend to satiety signals and adjust meal size).

Design Plan

Study type: Experiment - A researcher randomly assigns treatments to study subjects, this includes field or lab experiments. This is also known as an intervention experiment and includes randomized controlled trials.

Blinding: For studies that involve human subjects, they will not know the treatment group to which they have been assigned.

Is there any additional blinding in this study? To attempt to reduce the likelihood of aim guessing, participants will be recruited to a study labelled as 'a study of diet on cognitive function'.

Study design: An experimental, within-subjects design. Participants will be asked to visit the lab for three consecutive weeks to complete some questionnaires and eat meals at lunch time and dinner time. Participants will complete all three conditions – low energy density, medium energy density and high energy density meals which will be eaten ad-libitum. Participants will be provided with a box of snacks to eat throughout the day if they wish to, and will return to the lab for dinner, where they will be served an ad-libitum meal and a dessert.

Randomization: Participants will complete all three conditions. The order the conditions are presented to participants will be randomised prior to arrival.

Sampling Plan

Existing Data: Registration prior to creation of data

Explanation of existing data: N/A

Data collection procedures: Participant database. If required, participants will also be recruited from the local community (e.g. adverts on social media/posters in the university)

Inclusion criteria:

- Currently reside in the UK
- Over the age of 18 years
- Fluent English speaker
- Like the test foods
- Have a BMI between the ranges of 18.5 and 35.

Exclusion criteria:

- Pregnant/breastfeeding
- Partaking in a fast or other restrictive eating for religious reasons at time of participation

- Currently following a diet
- On medication that affects appetite
- Being a smoker
- Current or historic eating disorder
- Dietary restrictions/intolerances including:
 - Any allergies
 - Vegan/vegetarian
 - Gluten-free
 - Dairy-free
 - Sugar-free

Procedure:

Once signed up, participants will attend a short screening session, where they will be asked to complete a medical history questionnaire, a baseline demographic questionnaire, have their height and weight measured, and check they like the test foods on offer.

Participants will be told upon registration that they should have the same breakfast the morning of each session. Arrangements will be made for the participants to arrive at the lab around the time they would usually eat their lunch (11.30-2.30) and be allocated to one of the following groups for each session (order randomised):

- Low energy density lunch
- Medium energy density lunch
- High energy density lunch

Upon arrival, participants will be asked to complete some questionnaires whilst their meal is being prepared. Questionnaires include:

- All three visits
 - Level of hunger/fullness
 - Cognitive task
- Final visit
 - Follow-up questionnaire (Satiety responsiveness questionnaire, compensatory health beliefs)
 - Aim guessing/ranking meals

Participants will be provided with their lunch (loaded fries). There will be a large bowl of chips (low ED; 1.17kcal/g; medium ED; 1.74kcal/g; high ED; 3.00kcal/g), and a separate large bowl of chilli at low (1.1kcal/g), medium (1.6kcal/g) or high (3.2kcal/g) ED. Participants will serve themselves from the provided bowls. The three different chilli recipes will be made in the lab using a standardised procedure. ED will be varied by altering the ingredients used, and proportions of ingredients. A review of existing energy density manipulation studies(14) found that very similar effects were identified in studies whether the nutritional composition was altered or not, so it was deemed appropriate to alter the nutritional content of the meal. Details of all food served are shown in Table 1. These recipes will be made in bulk, frozen and labelled clearly so each portion can be defrosted and prepared for each participant on the day of consumption.

Loaded fries were chosen as the test meal, as it is a food frequently served in the out-of-home food sector, and a meal which is relatively simple to manipulate in terms of energy density. The recipes

were tested several times to ensure they were equally appetising, and sent to the SGS Cambridge Analysis Lab to ensure they contained the expected energy densities.

Throughout the study, random samples of each chilli will be sent off to the SGS Cambridge Analysis Lab to test for nutritional content of each of the products. This will ensure that nutritional components remain consistent over the course of the study. We plan to do this twice over the course of data collection.

The amount of food served will fill a large serving bowl (750g of each chilli, with 500g of chips). Participants will be left alone and asked to eat as much or as little of their meal as they would like. When they have finished their meal, participants will be told to call the researcher back in to continue the study. The plate will be taken from participants and any remaining food weighed in order to calculate total grams and energy consumed. Participants will be asked to rate sensory aspects of the meal.

After each lunch session, participants will be provided with a snack box, and told they can eat as much or as little of what is provided as they wish.

Participants will return for an evening session to eat their dinner (4.30-6.30). They will be required to bring the snack box, and any remaining snacks with them. Here, participants will once again be asked to complete hunger and fullness scales, and a cognitive task. Following this, a 3-cheese pasta ready meal (800g) with a side of mixed vegetables (225g) will be provided for participants to serve themselves. Once participants have eaten all they wish to of the pasta meal, dessert will be provided (brownie bites and flapjack bites) which once again, they can help themselves to as much or as little as they would like.

After their final study dinner, participants will be given a follow-up questionnaire to assess compensatory health beliefs and satiety responsiveness. They will also be asked to guess the aim of the study and rank the foods they have eaten for each lunch session in terms of healthiness. Following this they will be fully debriefed.

Table 1: All test foods

	Low ED			Medium ED			High ED		
	g	kcal	£	g	kcal	£	g	kcal	£
<u>LUNCH</u>									
<i>Potatoes</i>	500	585	£1.27	500	870	£0.97	500	1500	£2.16
<i>Chilli</i>	750	885	£3.17	750	1275	£3.14	750	2430	£3.92
<i>Water</i>	500	0	£0.00	500	0	£0.00	500	0	£0.00
<u>DINNER</u>									
<i>Ready meal</i>	800	1164	£3.50	800	1164	£3.50	800	1164	£3.50
<i>Mixed vegetables</i>	225	84	£1.50	225	84	£1.50	225	84	£1.50
<i>Water</i>	500	0	£0.00	500	0	£0.00	500	0	£0.00
<u>DESSERT</u>									
<i>Brownie bites</i>	220	860	£2.25	220	860	£2.25	220	860	£2.25
<i>Flapjack bites</i>	280	1260	£2.25	280	1260	£2.25	280	1260	£2.25
<i>Water</i>	500	0	£0.00	500	0	£0.00	500	0	£0.00
<u>SNACKBOX</u>									
<i>Apple</i>	268	142.04	£0.80	268	142.04	£0.80	268	142.04	£0.80
<i>Cereal bar</i>	60	232.8	£0.67	60	232.8	£0.67	60	232.8	£0.67
<i>Crisps</i>	50	270	£0.18	50	270	£0.18	50	270	£0.18
<i>Carrot batons</i>	100	43	£0.58	100	43	£0.58	100	43	£0.58

<i>Biscuits</i>	22	104.72	£0.17	22	104.72	£0.17	22	104.72	£0.17
<i>Dried fruit and nut mix</i>	25	133	£0.55	25	133	£0.55	25	133	£0.55
Chilli									
<i>Mince (5%/15%/20%)</i>	250		£1.43	313		£1.82	769		£2.75
<i>Onion</i>	75		£0.04	68		£0.03	12		£0.01
<i>Carrot</i>	100		£0.05	52		£0.03	6		£0.01
<i>Mushroom</i>	100		£0.30	52		£0.16	6		£0.02
<i>Tomato</i>	100		£0.27	52		£0.14	6		£0.02
<i>Tinned tomatoes</i>	300		£0.34	209		£0.23	123		£0.14
<i>Cumin</i>	2		£0.04	2		£0.04	2		£0.05
<i>Worcester sauce</i>	2		£0.01	2		£0.01	2		£0.02
<i>Garlic</i>	10		£0.16	10		£0.16	12		£0.19
<i>Beef stock</i>	150		£0.10	104		£0.07	62		£0.04
<i>Kidney beans</i>	100		£0.21	78		£0.16	68		£0.14
<i>Oregano</i>	1		£0.06	1		£0.06	1		£0.07
<i>Cream</i>	50		£0.16	52		£0.23	123		£0.46
<i>Salt</i>	1		£0.02	1		£0.02	1		£0.02
<i>Pepper</i>	1		£0.02	1		£0.02	1		£0.02
Full portion when prepared	750	885	£3.17	750	1170	£3.14	750	2430	£3.92
KJ/100g		480			540			1348	
Kcals/100g		114			156			324	
Fat/100g		4.8			8.7			24.5	
Carbs/100g		10.7			7.2			7.3	
Protein/100g		7.2			12.1			18.7	
Moisture/100g		76.1			70.2			47.2	

Variables

Manipulated variables: Whether participants are provided with a low, medium or high energy dense lunch.

Test meals: The ingredients to make all meals will be purchased from the supermarket Tesco, and prior to and during data collection samples will be sent off to the SGS Cambridge Analysis Lab to test for consistency in nutritional content within each of the products.

Measured variables:

- Grams consumed
 - o Meal components will be weighed in their serving bowls before and after lunch and dinner to determine how much has been consumed by each participant.
- Energy consumed
 - o To calculate energy consumed at lunch and dinner the total grams consumed will be multiplied by the energy density of the product (kcal/g, as obtained from the lab or food packaging of ready-made products). Energy for each snack provided will be calculated prior to giving participants snack boxes.

Participant characteristics

In order to characterise the sample and present outcomes by individual participant variables, participants will be asked to report their gender, age and ethnicity. Height and weight data will also

be collected to calculate body mass index (BMI), so participants can be classed as having underweight, healthy weight, overweight or obesity.

Measures of socioeconomic position (SEP)

Three measures of SEP will be taken:

Participants will be asked to report their highest educational qualification. If they are still studying, they should report the diploma they are currently studying for. The categories provided will be:

- Less than high school
- High school completion
- College or foundation degree
- Bachelor's degree
- Master's degree
- Doctoral or professional degree

A subjective measure of their socioeconomic position using the MacArthur Scale of Subjective Social Status (SSS) (19). SSS will be recorded as this measure has been found to have strong associations with overweight and obesity(20).

Childhood SES(21): for this measure, participants will be asked to provide the educational attainment and occupation of each primary caregiver at the time the individual was 8-10 years old. Parental educational attainment will be reported in 6 categories, if there are two caregivers, the average will be calculated.

- 1 = less than high school
- 2 = high school
- 3 = 2-year degree
- 4 = 4-year degree
- 5 = master's degree
- 6 = doctorate/professional degree

Parental occupation will be coded independently by two researchers using Hollingshead's 9-point scale(22), and inter-rater reliability assessed.

Sensory ratings (Appendix E)

Participants will be asked to complete sensory ratings once they have finished their meal for:

- Pleasant
- Sweet
- Savoury
- Salty
- Familiar
- Filling
- Soft
- Appetising (visually)

All will be presented on visual analogue scales ranging from 1-100 anchored by "not at all" and "extremely" respectively.

Measure of hunger/fullness

Situational levels of hunger and fullness will be obtained before and after lunch and dinner by using visual analogue scales ranging from 1-100 anchored by “not at all” and “extremely” respectively.

Satiety responsiveness (Appendix F)

Participants will complete a satiety responsiveness subscale of the Adult Eating Behaviour Questionnaire (AEBQ)(23)

Compensatory health beliefs (Appendix G)

Participants will complete a compensatory health beliefs questionnaire. This will be made up of 8 items, from the exercise and portion size subscales from the diet-related Compensatory Health Beliefs Scale (Diet-CHBS)(24). Participants are required to rate all items from 1 (not at all) to 5 (very much) for how much the compensatory health belief matches their own beliefs e.g. “To maintain your weight, it is fine to eat a high caloric snack in between meals, if you compensate for this by eating a smaller portion later in the day”.

Food diary

At each lunch session, participants will be asked to report any foods or beverages (excluding water) consumed the morning of the study, to ensure nothing was consumed in the two hours prior to the study, and to ensure breakfast is similar across the three sessions. At each dinner session, participants will be asked to report any foods or beverages (excluding water) consumed that were not provided by the researchers.

Aim guessing (Appendix H)

At the end of their final visit, participants will be asked what they believe the aims of the study to be. Anyone that guesses the study aims to be investigating the influence of energy density on intake (e.g. the healthiness/energy content of meal on how much was consumed at lunch time or at dinner time) will be coded as being aware of study aims. One researcher will code awareness of aims and a second researcher will independently verify.

Participants will then be asked to rank the three lunch time meals in terms of level of energy density.

Additional tasks

Additional tasks will be completed to account for the study description of ‘A study of diet on cognitive function’. Before and after each lunch and dinner meal, participants will complete a Stroop task.

Study flow

	Visit 1	Visit 2	Visit 3
RECRUITMENT	Participants who could not take part in the previous mood, diet and sleep study will be contacted to take part in this study (Appendix A)		

<p>SCREENING</p>	<p>Participants will come into the lab to be screened. This will involve: Medical history questionnaire Baseline demographic questionnaire (Appendix B) Height and weight measurement Ensuring they like all test foods.</p>		
<p>INFORMED CONSENT</p>	<p>Participants will be asked to read the information sheet (Appendix C). Participants who want to proceed will read the consent form and tick a box providing their consent (Appendix D).</p>		
<p>RANDOMISATION</p>	<p>Before their first session, the order that meals are presented to participants will be randomized.</p>		
<p>BASELINE ASSESSMENTS <i>(Inquisit)</i></p>	<p>Participants will complete a baseline demographic questionnaire, measures of hunger and fullness, and a cognitive task</p>	<p>Participants will complete measures of hunger and fullness and a cognitive task</p>	<p>Participants will complete measures of hunger and fullness and a cognitive task</p>
<p>LUNCH</p>	<p>Participants will be provided with a glass of water and their lunch (low ED, medium ED and high ED) to serve themselves. After eating the meal, participants will be asked to provide sensory ratings (Appendix E).</p>	<p>Participants will be provided with a glass of water and their lunch (low/medium/high ED) to serve themselves. After eating the meal, participants will be asked to provide sensory ratings.</p>	<p>Participants will be provided with a glass of water and their lunch (low/medium/high ED) to serve themselves. After eating the meal, participants will be asked to provide sensory ratings.</p>

<p>POST MEAL</p>	<p>Participants will complete the cognitive task.</p> <p>Measures of hunger and fullness will be taken again.</p> <p>Participants will be asked to report any foods or beverages that had been consumed prior to arriving at the lab.</p>	<p>Participants will complete the cognitive task.</p> <p>Measures of hunger and fullness will be taken again.</p> <p>Participants will be asked to report any foods or beverages that had been consumed prior to arriving at the lab.</p>	<p>Participants will complete the cognitive task.</p> <p>Measures of hunger and fullness will be taken again.</p> <p>Participants will be asked to report any foods or beverages that had been consumed prior to arriving at the lab.</p>
<p>POST-SESSION</p>	<p>Participants will take home a snack box. They will be told they can eat as many or as few of the snack items as they wish.</p>	<p>Participants will take home a snack box. They will be told they can eat as many or as few of the snack items as they wish.</p>	<p>Participants will take home a snack box. They will be told they can eat as many or as few of the snack items as they wish.</p>
<p>DINNER</p>	<p>After completing hunger and fullness ratings and a cognitive task again, participants will be provided with a glass of water and a ready-meal for dinner, which they can serve themselves.</p> <p>After dinner, participants will be provided with a dessert to have as much or as little of as they like.</p>	<p>After completing hunger and fullness ratings and a cognitive task again, participants will be provided with a glass of water and a ready-meal for dinner, which they can serve themselves.</p> <p>After dinner, participants will be provided with a dessert to have as much or as little of as they like.</p>	<p>After completing hunger and fullness ratings and a cognitive task again, participants will be provided with a glass of water and a ready-meal for dinner, which they can serve themselves.</p> <p>After dinner, participants will be provided with a dessert to have as much or as little of as they like.</p>

POST-MEAL	Participants will complete hunger and fullness ratings and a cognitive task again.	Participants will complete hunger and fullness ratings and a cognitive task again.	Participants will complete hunger and fullness ratings and a cognitive task again. Participants will complete measures of satiety responsiveness (Appendix F) and compensatory health beliefs (Appendix G).
DEBRIEFING			Aim guessing in an open-ended response format will be provided to participants (Appendix H). Following this, participants will be asked to rank the meals from the three weeks in order of energy density. Participants will be debriefed on study aims (Appendix H).
DATA MANAGEMENT	<p>The result files will contain:</p> <ul style="list-style-type: none"> ○ Participant unique ID (randomly generated) ○ Demographic and questionnaire data ○ Amount of each lunch meal consumed (g) ○ Energy consumed for each lunch (kcal) ○ Snacks consumed ○ Amount of dinner and dessert consumed (g) ○ Energy consumed for dinner and dessert (kcal) 		

Analysis Plan

Participant characteristics:

Only participants who have completed the entire study (all three visits) will be included in analysis. We will report analyses with any participants who guess the aims of the study included and excluded.

If any participants do not follow study instructions (e.g. do not consumer any or only a very small amount of any of the food (<50kcal) then they will be removed from primary analyses.

Participant characteristics will be presented in a table. Data will include age, gender, ethnicity, BMI, highest education level, perceived social status, childhood SEP, compensatory health beliefs and satiety awareness. Continuous variables will be summarised by means and standard deviations, categorical variables will be summarised by counts and percentages.

Primary analyses:

Two repeated-measures, within-subjects ANOVAs will assess lunchtime (manipulated meal) kcal and gram intake across the three conditions. Where significant main effects are identified, post-hoc pairwise comparisons will be performed to identify where these differences exist. Sensory ratings of the three meals will be compared using repeated-measures, within-subjects ANOVAs to assess whether all meals were rated equally. Results will be considered statistically significant at $p < 0.05$.

Secondary analyses:

Two repeated-measures, within-subjects ANOVAs will assess later kcal and gram intake (dinner, dessert and snacks) across the three conditions (low ED, medium ED and high ED). Where significant main effects are identified, post-hoc analyses will be performed to identify where these differences exist.

A repeated-measures, within-subjects ANOVA will assess daily energy intake (sum of lunch, dinner, dessert, snacks and additional food) across the three conditions. Where significant main effects are identified, post-hoc analyses will be performed to identify where these differences exist.

To account for multiple comparisons, results for secondary analyses will be considered significant at $p < .01$.

Sensitivity analyses:

We will examine evidence of extreme outliers (+3 standard deviations from the session mean) in grams consumed for each test food, and for any outcomes identified as outliers we will examine the effect of winsorizing the outlier.

If we find evidence that meals differ in sensory ratings then we will also examine if results remain the same when sensory ratings are controlled for in analyses as a covariate.

We will also examine if results remain the same among participants who accurately identify the differences in energy density between foods vs. participants who do not. Alternatively, if only a small number of participants are unable to identify the correct order of energy density then we will examine if results remain the same when excluded.

We will report whether sensitivity analyses deviate from primary analyses (e.g. if significant findings become non-significant and vice versa).

Transformations: N/A

Inference criteria: Results for primary analyses will be considered significant at $p < 0.05$, and to account for multiple comparisons, secondary analyses will be considered significant at $p < 0.01$.

Data exclusion: If participants drop out of the study, any data will be excluded from analyses.

Missing data: For participants who complete all three study sessions, it is not anticipated that missing data will be a problem. If there is missing data, participants will be excluded from analyses.

Exploratory analysis:

Other:

Sample size:

A previous study provided three desserts differing in energy density to participants over three consecutive weeks. Grams consumed and kcals consumed for each dessert were recorded. The

influence of energy density on intake (g) was significant ($p < .001$), with a partial eta squared of 0.4 (large effect). The influence of energy density on kcals eaten was also significant ($p < .001$) with a partial eta squared of 0.7 (large effect). As the relative energy density of the meals will be unknown to participants (desserts were familiar in the previous study), it is anticipated that effect sizes will be smaller than observed in the previous study. We will power the present study to be able to detect a medium effect size of $f = 0.25$ through a repeated-measures, within factors ANOVA consisting of three measures at 0.95% power. This will require a minimum sample of 28 participants.

If the findings of the ANOVA show significant differences between the three conditions, post-hoc analyses will be conducted. In the previous study, the smallest effect observed had a Cohens D of 0.52. We will power the present study to be able to detect effects of this size at 0.8% power in post-hoc t-tests, which will require a minimum sample of 32 participants.

Therefore, we will aim to recruit a minimum of 32 participants for this study.

Appendix A: Recruitment text

This is a study exploring the interaction between diet and cognitive function. If you wish to take part, you will attend a screening session at the university of Liverpool (Eleanor Rathbone building) where you will complete a medical history questionnaire and have your height and weight measured.

If you are eligible, you will be asked to come into the lab (Eleanor Rathbone building, University of Liverpool) for three consecutive weeks for lunch and dinner. Before and after each meal you will be asked to complete a cognitive task.

The lunch provided will be three variations of loaded fries (with beef chilli). You will be asked to serve yourself the amount you would like to eat.

After lunch, you will be given a snack box to eat throughout the day if you wish, and when you return in the evening, you will be given a three-cheese pasta for dinner, followed by a dessert of chocolate brownies.

Following three days of testing you will complete a number of questionnaires.

If you would like to take part, please make sure:

- You currently reside in or around Liverpool and are able to travel to the university for a screening session and lunch and evening meals one day a week for three consecutive weeks.
- You like the foods on offer for lunch and dinner.
- You are 18 years or older
- You are not taking any medication that affects your appetite
- You are a fluent English speaker
- You are not pregnant or breastfeeding
- You are a non-smoker
- You are not partaking in a fast or other restrictive eating for religious reasons at the time of participation
- You have none of the following dietary restrictions:
 - Vegetarian/vegan
 - Gluten-free
 - Dairy-free
 - Sugar-free
 - Any food allergies

Appendix B: Baseline questionnaire

1. Gender

- Male
- Female
- Other

2. Age:

3. Ethnicity:

- White English/Welsh/Scottish/Northern Irish/British
- White Irish
- Any other White background
- White and Black Caribbean
- White and Black African
- Any other mixed/multiple ethnic background please describe
- Indian
- Pakistani
- Bangladeshi
- Chinese
- Other Asian
- African
- Caribbean
- Arab
- Any other ethnic group

4. What is your highest educational qualification?

- Less than high school
- High school completion
- College or foundation degree
- Bachelor's degree
- Master's degree
- Doctoral or professional degree

5. This is an attention check. How many times have you visited the planet Mars?

- Several times
- Just once
- Never

Think of a ladder (see image) as representing where people stand in society. At the top of the ladder are the people who are best off—those who have the most money, most education and the best jobs. At the bottom are the people who are worst off—who have the least money, least education and the worst jobs or no job. The higher up you are on this ladder, the closer you are to people at the very top and the lower you are, the closer you are to the bottom. Where would you place yourself on the ladder?



6. Choose the number whose position best represents where you would be on this ladder:

7: Please state the highest educational attainment of your primary caregiver(s) when you were aged 8-10.

1 = less than high school

2 = high school

3 = 2-year degree

4 = 3/4-year degree

5 = master's degree

6 = doctorate/professional degree

Primary caregiver 1 _____

Primary caregiver 2 _____

8: Please state the occupation of your primary caregiver(s) when you were aged 8-10.

Primary caregiver 1 _____

Primary caregiver 2 _____

Appendix C: Participant information sheet



A study of diet and cognitive function

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. We would like to stress that you should only agree to take part if you want to.

What is the purpose of the study?

The purpose of the study is to understand the impact of diet on cognitive function.

Why have I been chosen to take part?

We are recruiting volunteers who fulfil the following criteria:

- You currently reside in or around Liverpool and are able to travel to the university for lunch one day a week for three consecutive weeks.
- You like all of the foods on offer(chips, chilli, three-cheese pasta, chocolate brownie, flapjack)
- You are 18 years or older
- You are a fluent English speaker
- You are not pregnant or breastfeeding
- You are not a smoker
- You are not currently on any medication that affects your appetite
- You are not partaking in a fast or other restrictive eating for religious reasons at the time of participation
- You have none of the following dietary restrictions:
 - Vegan
 - Vegetarian
 - Gluten-free
 - Dairy-free
 - Sugar-free

Do I have to take part?

No. Participation in this research is completely voluntary. You are free to withdraw at any time without explanation and without incurring a disadvantage.

What will happen if I take part?

Following a screening session where you will complete some questionnaires, a medical history and have your height and weight measured, you will be required to come to the lab (Eleanor Rathbone Building, University of Liverpool) for your lunch and dinner one day a week for three consecutive weeks. You will be asked to provide some information about yourself (e.g., age, gender), before completing a cognitive task. You will then be provided with lunch and asked to complete the cognitive task again. You will return later in the day for an evening meal, where the same cognitive task will be completed before and after you eat the meal. So that your awareness of the study hypotheses does not affect your behaviour in the study we provide more detailed information about the study aims at the end of the study. If you feel uncomfortable about this then you are free not to participate in this study. The study should take approximately 180 minutes total (30 minutes per visit). You will be reimbursed £60 for your time, plus travel expenses.

How will my data be used?

The University processes personal data as part of its research and teaching activities in accordance with the lawful basis of 'public task', and in accordance with the University's purpose of advancing education, learning and research for the public benefit. University of Liverpool employee Amy Finlay (a.finlay@liverpool.ac.uk) acts as the Data Protection Officer for this study and any queries relating to the handling of your personal data can be sent to her. Further information on how your data will be used can be found in the table below.

How will my data be collected?	Through measurement of in-person tasks, questionnaires and food consumed.
How will my data be stored?	On a password protected computer server.
How long will my data be stored for?	Your personal data will be stored for up to 28 days and then deleted. All other information will be stored indefinitely.
What measures are in place to protect the security and confidentiality of my data?	We will store all data on password protected computer servers and we never share any of your personal data outside of the research team for this project.
Will my data be anonymised?	After the study your personal information will be stored separately from your other questionnaire responses to create an anonymised data set. After 28 days all personal information will be deleted, but up to this point you can contact us and ask to see your information or have it deleted.
How will my data be used?	Your anonymised data will be combined with other participants' data in order to be analysed.
Who will have access to my data?	The research team for this project will have access to your data.

Will my data be archived for use in other research projects in the future?	After the research team have anonymised your data and completed this research project, they will place the anonymised data sets on an archive (e.g. Open Science Framework) in case any other researchers want to use it for future research purposes.
How will my data be destroyed?	Your personal data will be destroyed electronically (deleting the files and removing them from the computer server).

Are there any risks in taking part?

There are no anticipated risks to you if you take part in the study.

Are there any benefits in taking part?

There are no direct benefits, other than the monetary payment.

What will happen to the results of the study?

We intend to publish the results from this study in a scientific journal. However, as explained above any personal information you provide is deleted before this and you would therefore not be identifiable in report. If you are interested in the results of the study, please let us know and we will share the results of the study with you when we publish it.

What will happen if I want to stop taking part?

You are under no obligation to take part in this study; it is completely your choice. If you do decide to take part, you are free to withdraw at any time and without giving any reason or explanation. Data collected up until the period you withdraw may be used, but only if you are happy for this to be done. Otherwise you may request that your data be destroyed and no further use is made of them. We cannot guarantee payment if you do not complete all three visits.

What if I am unhappy or if there is a problem?

If you are unhappy, or if there is a problem, please feel free to let us know by contacting Amy Finlay or Eric Robinson (contact details below) and we will try to help. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer on 0151 794 8290 (ethics@liv.ac.uk). Please provide details of the name or description of the study (so that it can be identified), the researcher(s) involved, and the details of the complaint you wish to make.

Who can I contact if I have further questions?

Please contact the principle investigator: Amy Finlay
 2.19, Eleanor Rathbone Building
 University of Liverpool,
 Liverpool,
 L69 7ZA,
 email: a.finlay@liverpool.ac.uk

or the senior researcher: Prof. Eric Robinson
email: robinsoe@liverpool.ac.uk

I confirm I have read the information sheet

- Yes

Appendix D: Consent page

A study of diet and cognitive function

I confirm that I have read and have understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I understand that taking part in the study involves completing tasks, questionnaires, and eating the lunch and dinner provided.

I understand that my participation is voluntary and that I am free to stop taking part and can withdraw from the study at any time without giving any reason and without my rights being affected. I also understand that I have the right to lodge a complaint.

I understand that the information I provide is for research purposes and it will be held securely in line with data protection requirements at the University of Liverpool. In addition, I understand that personal information collected about me that can identify me will never be shared beyond the study team.

I understand that shortly after completing the study, researchers will keep my personal data and store it separately from my other questionnaire responses for up to 28 days on a computer, so that my anonymised questionnaire responses can later be deposited in an online data archive for sharing and used by other authorised researchers to support other research in the future.

I understand that I can ask for access to any of the information I provide and I can request the destruction or alteration of that information if I wish for up to 28 days after participating in the study. I understand that following this I will no longer be able to request access to or withdrawal of the information I provide because this information will have been deleted.

I provide my consent as a legal basis for the processing of my data as detailed previously, including the purposes of data processing, recipients of data and the right to withdraw my data.

I agree and consent to take part in the above study

- Yes

Appendix E: Sensory ratings:

Please rate the meal you just had on the following scales:

Pleasant



Sweet



Salty



Savoury



Appetising (visually)



Familiar



Filling



Soft



Appendix F: Satiety responsiveness

		<i>Strongly disagree</i> 1	<i>Disagree</i> 2	<i>Neither agree nor disagree</i> 3	<i>Agree</i> 4	<i>Strongly agree</i> 5
1.	<i>I often leave food on my plate at the end of a meal.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.	<i>I often get full before my meal is finished.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.	<i>I get full up easily.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.	<i>I cannot eat a meal if I have had a snack just before.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix G: Compensatory Health Beliefs

		<i>Strongly disagree</i> 1	<i>Disagree</i> 2	<i>Neither agree nor disagree</i> 3	<i>Agree</i> 4	<i>Strongly agree</i> 5
1.	<i>To maintain your weight, it is fine to do less exercise if you eat small portions</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.	<i>To maintain your weight, it is fine to have less exercise if you eat products with a front-of-package logo</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.	<i>When I eat less, it's not necessary to have a lot of exercise</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.	<i>When I mainly eat products with a front-of-package logo, it is not necessary to have a lot of exercise</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.	<i>If I eat a small meal, it's fine to have a larger portion during the next meal</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.	<i>To maintain your weight, it is fine to eat a large meal, if you eat a small portion during the next meal</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7.	<i>To maintain your weight, it is fine to eat a high caloric snack in between meals, if you compensate for this by eating a smaller portion later in the day</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8.	<i>If I eat a small meal, there is no harm in eating more cookies and candies</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix I: Debriefing text

In this study we were interested in the effect of energy density (measured by calories per gram of food) on consumption – where the energy density of the loaded fries was different each week. Energy density was altered by changing the ingredients (i.e. 20% fat beef mince/15% fat beef mince/5% fat beef mince) or the proportions of ingredients (i.e. a greater proportion of vegetables). All participants were presented with the same three meals, each in a random order.

We wanted to investigate whether people compensate when given a less healthy food option by eating a smaller amount compared to when they are given less unhealthy options. Additionally, we wanted to see if people compensate later in the day, by eating a smaller portion for dinner when they had a less healthy meal at lunch.

We hypothesised that individuals would compensate more for the least healthy option by eating less (whether at lunch time or dinner time).

The questionnaire about satiety responsiveness and compensatory health beliefs will be used to test any characteristics and motivations that may impact the amount of food eaten.

If this study has raised any issues regarding your weight or eating behaviours, we recommend contacting your doctor.

The following NHS page provides information and guidance on eating a healthy, balanced diet:
<https://www.nhs.uk/live-well/eat-well/>

Thank you very much for your participation in our study.

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