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Short Communication

# Food taste and macronutrient content: Different associations with self-reported hunger and desire to eat

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ABSTRACT

*Background:* Self-reported hunger and desire to eat are frequently measured in relation to food consumption, with differences between responses sometimes reported, suggesting subtle differences between the two concepts. This study sought to investigate potential differences between self-reports of hunger and desire to eat in association with desire-to-consume foods differing in taste, macronutrient content and usual consumption context.

*Methods:* On 1 to 4 occasions, 172 participants completed questionnaire measures of hunger, desire to eat and desire to consume 60 different commercially-available foods of sweet and savoury tastes, varying in carbohydrate, fat and protein content, that are usually consumed both as part of a meal or as a snack.

*Results:* Using regression analyses for clustered data (338 questionnaire responses from 172 individuals), strong correlations were found between self-reported hunger and desire to eat (Beta = 0.82, $p < 0.01$). Hunger ratings were also positively associated with desires for savoury high-protein meal items (Beta = 3.471, $p = 0.02$), while desire to eat ratings were positively associated with sweet high-carbohydrate and high-fat meal items, such as cakes and desserts (Beta = 4.182, $p = 0.02$), and negatively associated with sweet high-carbohydrate snack items, such as fruit and candy (Beta = −3.809, $p = 0.03$).

*Conclusions:* These findings suggest that, although hunger and desire to eat are closely related, they are individual concepts, and can be distinguished by desire-to-consume differing foods based on taste and macronutrient content. The specific foods further suggest associations between self-reported hunger and biological need, and between self-reported desire to eat and hedonic or emotional desires.

## 1. Introduction

Hunger is a universal sensation that every human experiences. It is a response to the biological need to eat to fuel metabolic processes and to maintain homeostasis in the body over time (Beaulieu & Blundell, 2021; Hopkins, Beaulieu, Myers, Gibbons & Blundell, 2017). This homeostatic view on food intake proposes that hunger is managed by tonic and episodic excitatory and inhibitory signals, such as changes in blood sugar or hormone levels (Beaulieu & Blundell, 2021; Hopkins et al., 2017). The interoception of hunger is subjective, but diverse physiological events such as a rumbling stomach, fatigue, or decreased energy levels are also common signals of hunger (Hopkins et al., 2017).

Alternatively, food consumption can be driven by an increased desire to eat in the absence of hunger or metabolic need (Berridge, Ho, Richard & DiFeliceantonion, 2010; Kringelbach, 2015). Evolutionarily, food used to be a scarce resource associated with high effort and uncertainties about the next meal. The human brain therefore was focussed on eating whenever food was available rather than stopping when satiated, or waiting until physiological symptoms of hunger arose (Johnson & Wardle, 2014). However, in the modern world, highly palatable foods are easily available in abundance in most developed countries (Johnson & Wardle, 2014). Therefore, eating is more often an act of pleasure (Kringelbach, 2015), that is associated with similar limbic pathway activations as substance abuse or monetary gain (Berridge et al., 2010; Kenny, 2011; Kringelbach, 2015). Diminished attention to homeostatic cues, alongside increased focus on hedonic signals, may be concerning as overconsumption, obesity, and disordered eating are rising public health concerns (Finlayson & Dalton, 2012; Johnson & Wardle, 2014).

Food taste and palatability enable humans to meet their homeostatic needs safely by identifying the sensory qualities of foods and deciding whether foods are safe to consume or not (van Dongen, van den Berg, Vink, et al., 2012). From a nutritional perspective, the satiating effects of

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foods are linked to their macronutrient composition, where protein, and to some extent fibre, are the macronutrients most often associated with satiety (Chambers, McCrickerd & Yeomans, 2015; Morell & Fiszman, 2017). Therefore, it can be argued that homeostatic hunger, or eating for fuel and satiety, may be associated with the consumption of high protein, and to some extent, high fibre foods (Chambers et al., 2015; Morell & Fiszman, 2017; van Dongen et al., 2012).

Associative learning over time further influences food choices and preferences based on the physical and affective consequences of the consumption of different foods (Chambers et al., 2015; Sclafani & Ackroff, 2012). Repeated work demonstrates that associations between tastes and the satisfaction of nutritional or homeostatic needs can be learnt (Appleton, Gentry & Shepherd, 2006; Chambers et al., 2015; Sclafani & Ackroff, 2012), to result in preferences for the tastes of foods that are satisfying (Appleton et al., 2006; Chambers et al., 2015; Gibson et al., 1995; Griffioen-Roose et al., 2012; van Dongen et al., 2012). Thus, the satisfaction of homeostatic hunger may be associated not only with the consumption of high protein (and high fibre) foods, but also with positive affective responses towards the tastes of these foods, i.e., for savoury tastes. Indeed, studies have shown associations between feelings of hunger and appetite for high-protein savoury tasting foods (Griffioen-Roose et al., 2012). Gibson et al., 1995 and Griffioen-Roose et al., 2012 also demonstrate explicit preferences for tastes associated with protein in situations of previous low protein consumption.

Similar learning may also occur based on context (Kramer et al., 1992; Wadhera & Capaldi, 2012), such that the satisfaction of homeostatic hunger may be associated not only with the consumption of savoury high-protein foods, but also with preferences for foods that are often consumed in *meals*, rather than as *snacks* (Wadhera & Capaldi, 2012). High-protein items are typically consumed in meals (Wadhera & Capaldi, 2012), and the satiating quality of a meal will likely result from the overall energy as well as the protein content (Gibson et al., 1995; Griffioen-Roose et al., 2012). Snacks are defined as ‘small amounts of food or drink usually consumed between main meals’ (Almoraie, Sagaan, Alharthi, et al., 2021; de Graaf, 2006), and, by contrast with meals, the foods most often consumed as snacks tend to be high in carbohydrate and fat content, rather than protein (Almoraie et al., 2021; de Graaf, 2006; Wadhera & Capaldi, 2012). While these foods may not be as satiating as equi-energetic protein-based foods (Almoraie et al., 2021), sweet, salty and high fat tastes are highly liked, and contribute significantly to food palatability and the pleasure gained from consumption (de Graaf, 2006; Griffioen-Roose et al., 2012; Sclafani & Ackroff, 2012; van Dongen et al., 2012). Sclafani & Ackroff, 2012, further suggest that the sensory properties of foods may “induce a hedonic experience that stimulates eating even in the absence of homeostatic need” (Sclafani & Ackroff, 2012, p. R1119).

The observations above suggest that ‘homeostatic’ hunger and ‘hedonic’ desire to eat may be associated with foods with differing tastes, macronutrient composition, and usual consumption as part of a meal or as a snack. Further research on the role of taste in food regulation would be of value. Conditions associated with overconsumption, obesity, and disordered eating are on the rise (Finlayson & Dalton, 2012; Johnson & Wardle, 2014), and further understanding of the drivers of food choice, alongside food consumption, would be beneficial. The identification of associations with hunger and desire to eat will further aid in a more complete understanding of these concepts, with the potential for alternative methods for their assessment. This work sought to extend existing understanding of the concepts of hunger and desire to eat in the context of homeostatic and hedonic consumption, and investigate further the relationships between these concepts and food taste, macronutrient composition and consumption context. Our focus was specifically on the associations between hunger, desire to eat, taste, macronutrient composition and usual consumption context, rather than on explaining hunger and desire to eat *per se*, or food consumption behaviours. It was hypothesised that self-reported hunger would be positively associated with an increased desire for savoury high-protein foods suited to consumption in a meal, while desire to eat would be positively associated with increased desires for savoury and sweet high-carbohydrate and high-fat foods more commonly consumed as snacks.

## 2. Methods

### 2.1. Design

The study used a questionnaire design, employing a single questionnaire.

### 2.2. Questionnaire

The questionnaire asked first for self-reports of interoceptive cues – hunger, thirst, desire to eat, and desire to drink. Immediately following this, participants were asked to rate their desire to consume 60 different food items at that time.

Interoceptive cues were rated on 100 mm visual analogue scales (VAS) (Flint et al., 2000), requesting hunger: (‘*How hungry are you?*’, anchors ‘*not at all*’, ‘*extremely*’); thirst (‘*How thirsty are you?*’, anchors ‘*not at all*’, ‘*extremely*’); desire to eat (‘*How strong is your desire to eat?*’, anchors ‘*not at all*’, ‘*extremely*’), and desire to drink (‘*How strong is your desire to drink?*’, anchors ‘*not at all*’, ‘*extremely*’).

Desire to consume the 60 different food items was requested with the instruction ‘*Now, please rate how strong is your desire to eat each of the following foods right now, on a scale of 0-7 where 0 refers to no desire at all, and 7 refers to a very high desire. Please think about the food as an individual item – do not combine the food with others or think of the food as part of a meal.*’ Food items were selected based on their usual taste (savoury, sweet) and perceived dominant macronutrient content (carbohydrate, fat, protein), as judged by three nutritionists / dietitians, such that around 10 food items of each food type (taste x macronutrient) were included. This process was undertaken to identify foods that the sample population would likely be familiar with, consume, and recognise as consistently high in specific tastes and macronutrient composition, while also ensuring that those perceptions were based on actual taste and macronutrient content. Foods were also chosen to be as distinct as possible from one another, allowing for individual participant differences. Food items were identified through collaborative discussion until a suitable number of foods were found, although foods for some categories were harder to find than others. Around ten foods per category were considered sufficient to describe the category in taste and macronutrient composition, without unnecessary burden for participants. Consideration of whether items were usually consumed as part of a meal or as a snack, to include both meal and snack items, was also given, although overlap between these categories is well recognised (Wadhera & Capaldi, 2012). Foods of each taste x macronutrient type are given in Table 1, with an example macronutrient profile and consideration here as a meal or a snack item. Foods were presented to participants in alphabetical order, such that food items from each category were distributed throughout the list. A copy of the complete questionnaire is provided in the Supplementary Materials.

### 2.3. Questionnaire administration

Questionnaires were administered in person in paper form within four studies investigating other aspects of food consumption. These studies were run as part of a training programme in research methods, and provided an opportunity for investigation of our research question without the need for a separate study and without emphasising our research interests, reducing over-thinking and the possibility of effects due to demand characteristics. The specific studies chosen were also conducted at a range of times throughout the day. The majority of studies investigating food consumption are, understandably, conducted around mealtimes, when hunger and desire to eat can be either extremely high or extremely low with limited room for nuance. Through

**Table 1**
Nutritional content of all included foods, with source of nutrient content provide in brackets.

| Food Item | Energy kcal / 100g | Carbo-hydrate g/ 100g | Fat g/ 100g | Protein g/ 100g | Food Item | Energy kcal / 100g | Carbo-hydrate g/ 100g | Fat g/ 100g | Protein g/ 100g |
|---|---|---|---|---|---|---|---|---|---|
| Savoury | | | | | Sweet | | | | |
| Carbohydrate | | | | | Carbohydrate | | | | |
| [M]Baked potato *(Asda Baking Potatoes)* | 107 | 23.0 | <0.5 | 2.5 | Banana | 90 | 20.0 | <0.5 | 1.2 |
| [M]Bread roll *(Warburtons Soft White Rolls)* | 265 | 46.6 | 3.9 | 9.7 | [M]Fruit pie *(Asda Apple Pie)* | 255 | 33.0 | 12.0 | 3.0 |
| [S]Carrot | 44 | 7.7 | <0.5 | <0.5 | [M]Honey | 329 | 81.5 | <0.5 | <0.5 |
| [M]Garlic bread *(Asda Garlic & Herb Baguette)* | 311 | 46.0 | 10.0 | 7.9 | Honeydew melon | 57 | 12.4 | <0.5 | 0.9 |
| [M]Green salad | 15 | 2.9 | <0.5 | 1.2 | [S]Jelly babies *(Maynard's Bassetts)* | 330 | 78.0 | 0.1 | 3.5 |
| [M]Mashed potato *(Aunt Bessie's)* | 113 | 15.0 | 4.5 | 2.1 | [S]Marshmallows *(Asda Marshmallows)* | 326 | 78.0 | <0.5 | 3.2 |
| [M]Pizza *(Asda Margherita Pizza)* | 238 | 29.0 | 7.7 | 12.0 | [S]Orange | 49 | 13.0 | 0.2 | 0.9 |
| [S]Plain crackers *(Jacob's Cream Crackers)* | 439 | 67.7 | 13.6 | 10.0 | [M]Rice pudding *(Ambrosia Rice Pudding Pot)* | 98 | 16.4 | 2.2 | 3.2 |
| Tomato | 18 | 3.9 | 0.2 | 0.9 | [M]Sweet pancakes *(Asda Sweet Pancakes)* | 268 | 36.0 | 11.0 | 4.5 |
| [S]Twiglets *(Twiglets)* | 421 | 57.0 | 13.4 | 12.4 | [S]Toffee popcorn *(Butterkist)* | 427 | 80.0 | 9.7 | 2.9 |
| [M]Vegetable curry *(Tesco Vegetable Tikka Masala)* | 135 | 18.1 | 5.1 | 3.1 | | | | | |
| Fat | | | | | Fat | | | | |
| [M]Cheese biscuits *(Jacob's Baked Cheddars)* | 533 | 46.8 | 33.0 | 10.6 | [S]Chocolate chip cookies *(Maryland Cookies)* | 483 | 65.0 | 22.0 | 5.5 |
| [M]Cheese sandwich biscuits *(Ritz Cheese Sandwich-Cracker)* | 517 | 58.6 | 31.0 | 6.9 | [S]Chocolate fingers *(Cadbury Dairy Milk Fingers)* | 513 | 61.0 | 26.0 | 7.5 |
| [M]Chips *(www.nutritionix.com)* | 312 | 41.0 | 14.5 | 3.4 | Digestive biscuits *(McVities Digestive)* | 483 | 63.6 | 21.3 | 7.0 |
| [M]Fried bread | 503 | 48.5 | 32.5 | 7.9 | [S]Doughnut (*Asda Pink Ring Donuts*) | 422 | 48.3 | 23.3 | 6.0 |
| [S]Plain crisps *(Walkers Ready Salted)* | 518 | 52.0 | 31.0 | 6.4 | [S]Flapjack (*Asda Baker Flapjack*) | 474 | 59.0 | 23.0 | 5.3 |
| [S]Pringles *(Pringles Cheese & Onion)* | 516 | 56.0 | 29.0 | 6.1 | [M]Fudge cake *(Asda Chocolate Fudge Cake)* | 408 | 50.0 | 21.0 | 4.6 |
| [S]Salted nuts *(KP Original Salted Peanuts)* | 615 | 5.6 | 51.0 | 30.0 | [S]Milk chocolate *(Cadbury Dairy Milk)* | 534 | 57.0 | 30.0 | 7.4 |
| [S]Salted popcorn *(Asda Popcorn)* | 488 | 50.0 | 26.0 | 8.2 | [M]Muffin *(Asda Blueberry Muffin)* | 386 | 43.0 | 22.0 | 4.4 |
| [M]Savoury biscuits *(Asda Multigrain Crackers)* | 506 | 58.0 | 20.0 | 8.6 | [M]Profiteroles *(Asda Profiteroles)* | 337 | 22.0 | 25.0 | 5.3 |
| [M]Yorkshire pudding *(Aunt Bessie's)* | 287 | 39.0 | 12.0 | 5.1 | [S]White chocolate *(Cadbury)* | 540 | 64.0 | 30.0 | 4.1 |
| Protein[*] | | | | | Protein | | | | |
| [M]Bacon *(Asda Back Bacon)* | 279 | 1.0 | 17.0 | 29.0 | [M]Cheesecake *(Asda New York Cheesecake)* | 342 | 29.0 | 23.0 | 5.7 |
| [M]BBQ chicken *(Asda BBQ Chicken Breast Slices)* | 137 | 4.9 | 1.7 | 25.0 | [S]Chocolate milkshake *(FRijj)* | 75 | 11.9 | 1.3 | 3.7 |
| [S]Kebab *(www.nutritionix.com)* | 295 | <0.5 | 21.2 | 24.7 | [M]Custard *(www.milk.co.uk)* | 95 | 16.4 | 2.0 | 4.0 |
| Meat curry *(Asda Chicken Tikka Masala)* | 120 | 4.1 | 6.6 | 10.0 | [S]Fruit yoghurt *(Yeo Valley Strawberry)* | 98 | 10.9 | 4.0 | 4.5 |
| [M]Plain omelette | 153 | 0.7 | 12.0 | 10.6 | [S]Fromage frais (*www.milk.co.uk*) | 99 | 13.2 | 2.9 | 5.8 |
| [S]Sausages *(Asda Pork Sausage)* | 311 | 2.0 | 27.0 | 15.0 | [M]Strawberry blancmange (*www.milk.co.uk*) | 89 | 36.0 | 2.0 | 4.0 |
| [M]Smoked salmon | 187 | <0.5 | 11.0 | 22.0 | [M]Tiramisu *(Asda Tiramisu)* | 227 | 31.0 | 8.1 | 4.5 |
| [M]Steak *(Rump Beef Steak, pan-fried)* | 143 | 1.6 | 4.8 | 23.0 | [S]Vanilla ice cream (*www.milk.co.uk*) | 169 | 22.0 | 8.2 | 3.2 |
| [M]Tuna *(John West, in Brine)* | 106 | 0.0 | 0.7 | 25.0 | [M]Vanilla mousse (*Milky bar*) | 127 | 17.6 | 4.0 | 4.9 |

[M] Included in analyses as a meal item.
[S] Included in analyses as a snack item.
[*] Sushi was originally also included in this category, but following administration of the questionnaire, with increasing availability in the market supply, we recognised huge variety in composition and consequently macronutrient content for this food, thus it did not easily fit any category and was not considered further.

the inclusion of studies conducted outside of mealtimes, we sought to specifically include assessments of hunger and desire to eat where these may differ. In all cases, the questionnaire relevant to this publication was completed independently of other study measures, largely as a distractor item, either as the first measure of the study or the second measure following questions on demographic variables. The questionnaire was completed between one and four times by study participants, each completion separated by one week, dependent on the primary purposes of each study. Up to four questionnaires per participant were subsequently included in our analyses allowing maximal use of the available data. Studies were given ethical approval, including the use of this questionnaire, by the Research Ethics Committees of the University of Bristol (ID 54876002) and Bournemouth University (ID 18129 / 46699 / 47388). In the majority of cases, participants of the studies were students of the same University as the researcher, and a minority of participants were members of the general public, aged 18–45 years. Participants were recruited via personal contacts and advertisements placed around the universities, including adverts placed on social media. All participants signed written informed consent prior to participating.

Questionnaire administration was halted when questionnaires for a minimum of 160 respondents were gained. This number of respondents was considered sufficient for the analyses to be conducted based on the number of pre-specified food categories (12 taste / macronutrient / meal/snack combinations) (Desai & Begg, 2008; Howell, 1997).

### 2.4. Analysis

Questionnaires were checked for completion prior to submission by each participant, and rectified where necessary. Data were then entered into Excel, scores for all food items in each pre-specified taste / macronutrient / consumption context food category were summed and divided by the number of items in the category, and Cronbach's alphas were calculated for each taste / macronutrient / consumption context scale to ensure reliability. Having computed Cronbach's alphas, systematic deletion of each individual food item in each scale was undertaken to assess the impact of each individual item on the consistency of each scale (Howell, 1997). Using this process, the Cronbach's alpha for the 'savoury high-carbohydrate meal' scale increased with the removal of the food item 'tomato', for the 'savoury high-protein meal' scale increased with the removal of the item 'meat curry', for the 'sweet high-carbohydrate meal' scale increased with the removal of the item 'honeydew melon', for the 'sweet high-carbohydrate snack' scale increased with the removal of the item 'banana', and for the 'sweet high-fat snack' scale increased with the removal of the item 'digestive biscuits'. These food items were thus removed from the respective scales to improve consistency.

Data were then analysed using multiple linear regression analyses for clustered data (Desai & Begg, 2008), where hunger and desire to eat were predicted by desire for savoury- and sweet-tasting foods high in carbohydrate, fat and protein, consumed as part of a meal and as snacks. Models were run with this structure rather than the reverse to allow consideration of and for all food categories simultaneously, and to reduce the likelihood of false positive (Type 1) errors. Participant ID was included as the cluster item, to account for within-subject consistency where questionnaires were completed more than once by the same respondent. Prior to all regression analyses, checks for multi-co-linearity revealed high correlations between 'savoury high-carbohydrate meal' and 'savoury high-fat meal' scales ($r = 0.773$), and between the 'sweet high-fat meal' scale and the 'sweet high-carbohydrate meal' ($r = 0.700$), the 'sweet high-protein meal' ($r = 0.779$), the 'sweet high-fat snack' ($r = 0.739$) and the 'sweet high-protein snack' scales ($r = 0.708$), thus 'savoury high-fat meal' and 'sweet high-fat meal' scales were removed from all analyses. This resulted in the inclusion in the two regression models of 10 food category scales: 'savoury high-carbohydrate meal', 'savoury high-carbohydrate snacks', 'savoury high-fat snacks', 'savoury high-protein meal', 'savoury high-protein snacks', 'sweet high-carbohydrate meal', 'sweet high-carbohydrate snacks', 'sweet high-fat snacks', 'sweet high-protein meal', and 'sweet high-protein snacks'. Data were analysed using SPSS Statistics (IBM) version 28 and Stata (Stata Corp. Inc.) version 18. Significance was set at $p < 0.05$.

## 3. Results

### 3.1. Questionnaire completion

One-hundred seventy-two individuals completed questionnaires: 46 males, 126 females, aged 18–45 years with a mean (SD) of 21.7 (5.3) years. These individuals provided 338 questionnaires for analysis: 176 questionnaires from 44 individuals who completed the questionnaire on 4 occasions, 24 questionnaires from 8 individuals who completed the questionnaire on 3 occasions, 36 questionnaires from 18 individuals who completed the questionnaire on 2 occasions, and 102 questionnaires from 102 individuals who completed the questionnaire only once. Descriptive statistics for all variables of interest are given in Table 2.

### 3.2. Hunger, desire to eat and desire for all foods

Ratings for hunger and desire to eat were first significantly associated with each other (172 individuals, $R^2 = 0.71$, MSE = 14.88, $F(1,171) = 735.22$, $p < 0.01$) with a co-efficient of 0.82, $p < 0.001$.

Ratings for hunger and desire to eat were significantly predicted by the regression models (172 individuals) (Hunger: $R^2 = 0.22$, MSE = 24.76, $F(10,171) = 6.59$, $p < 0.01$; Desire to eat: $R^2 = 0.24$, MSE = 24.98, $F(10,171) = 8.49$, $p < 0.01$). All co-efficients are given in Table 3. Hunger ratings were positively associated with desire for savoury high-protein meal items (Beta = 3.471, $p = 0.02$). Desire to eat ratings were positively associated with desire for sweet high-carbohydrate meal items (B = 4.182, $p = 0.02$), and negatively associated with desire for sweet high-carbohydrate snack items (B = −3.809, $p = 0.03$).

**Table 2**
Descriptive statistics for all variables.

| | | | Cronbach's alpha | Mean (SE) | Min. – Max. |
|---|---|---|---|---|---|
| Hunger (VAS score in mm (0–100)) | | | | 43.1 (1.9) | 0–100 |
| Desire to Eat (VAS score in mm (0–100)) | | | | 43.0 (2.0) | 0–100 |
| Desire for savoury-tasting food items (0–7)* | Carbohydrate | Meal | 0.86 | 2.50 (0.08) | 0–6.6 |
| | | Snack | 0.65 | 1.52 (0.07) | 0–6.3 |
| | Fat | Meal | 0.87 | 2.02 (0.08) | 0–6.2 |
| | | Snack | 0.80 | 1.93 (0.08) | 0–5.5 |
| | Protein | Meal | 0.84 | 2.13 (0.09) | 0–7.0 |
| | | Snack | 0.33 | 2.34 (0.09) | 0–7.0 |
| Desire for sweet-tasting food items (0–7)* | Carbohydrate | Meal | 0.76 | 2.18 (0.08) | 0–5.75 |
| | | Snack | 0.67 | 2.07 (0.07) | 0–6.0 |
| | Fat | Meal | 0.61 | 2.38 (0.08) | 0–6.0 |
| | | Snack | 0.85 | 2.65 (0.08) | 0–6.3 |
| | Protein | Meal | 0.80 | 1.95 (0.08) | 0–6.2 |
| | | Snack | 0.60 | 2.41 (0.07) | 0–6.5 |

* Desire for all food items rated on a 8-point scale from 0 to 7, where low scores demonstrate low desires, high scores demonstrate high desires.

**Table 3**
All results for regression models for hunger and desire to eat (338 questionnaires from 172 individuals).

| | | | Hunger | | | | Desire to eat | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Beta | SE | p | 95% CI | Beta | SE | p | 95% CI |
| Savoury | Carbohydrate | Meal | 2.755 | 1.93 | 0.16 | −1.058, 6.568 | 3.521 | 2.04 | 0.09 | −0.501, 7.544 |
| | | Snacks | 0.405 | 1.64 | 0.81 | −2.843, 3.655 | 0.317 | 1.77 | 0.86 | −3.183, 3.817 |
| | Fat | Snacks | 0.684 | 1.62 | 0.67 | −2.512, 3.880 | 1.111 | 1.64 | 0.50 | −2.134, 4.356 |
| | **Protein** | **Meal** | **3.471** | **1.48** | **0.02** | **0.559, 6.383** | 2.289 | 1.54 | 0.14 | −0.742, 5.320 |
| | | Snacks | 1.003 | 1.37 | 0.47 | −1.711, 3.716 | 1.252 | 1.35 | 0.36 | −1.413, 3.916 |
| Sweet | **Carbohydrate** | **Meal** | 3.493 | 1.97 | 0.08 | −0.405, 7.391 | **4.182** | **1.78** | **0.02** | **0.665, 7.699** |
| | | **Snacks** | −2.416 | 1.83 | 0.19 | −6.038, 1.207 | **−3.809** | **1.76** | **0.03** | **−7.285, −0.332** |
| | Fat | Snacks | 3.089 | 1.86 | 0.10 | −0.585, 6.762 | 3.191 | 1.96 | 0.11 | −0.683, 7.064 |
| | Protein | Meal | −2.853 | 2.10 | 0.18 | −7.008, 1.301 | −3.405 | 2.12 | 0.11 | −7.596, 0.787 |
| | | Snacks | −0.582 | 2.03 | 0.78 | −4.590, 3.426 | 1.240 | 2.03 | 0.54 | −2.769, 5.248 |

Significant effects ($p < 0.05$) are emboldened.

## 4. Discussion

Several key findings emerge from this study. First, a high positive correlation was found, unsurprisingly, between ratings for hunger and desire to eat. These findings suggest a common underlying mechanism to both perceptions, most plausibly associated with a biological need to fuel metabolic processes (Beaulieu & Blundell, 2021, Hopkins et al., 2017). Moreover, the strength of the correlation questions whether individuals differentiate between hunger and hedonic desires on a regular basis; a difficulty that is further undermined by functional and anatomical interconnectedness of the brain regions involved in both homeostatic and hedonic food consumption (Rossi & Stuber, 2018).

The correlation however is not perfect, and some individuals reported large differences in their ratings for hunger and desire to eat. Thus, while homeostatic hunger may be associated with an increased desire to eat for biological need, hedonic desires may also manifest independent of these biological needs (Berridge et al., 2010; Kenny, 2011; Kringelbach, 2015). These findings are consistent with literature that suggests independent processing of homeostatic drives and hedonic desires in food consumption (Berridge et al., 2010; Kenny, 2011; Kringelbach, 2015).

The regression results provide further evidence for a distinction between perceptions of hunger and desire to eat. First, there is a positive relationship between hunger and desire for savoury high-protein meal items, which is not present for desire to eat. This relationship contributes further evidence that protein content, savoury taste and meal consumption are associated (van Dongen et al., 2012; Wadhera & Capaldi, 2012); a relationship that most plausibly reflects learned associations about the value of protein-rich foods for the satisfaction of homeostatic needs (Griffioen-Roose et al., 2012; Morell & Fiszman, 2017; van Dongen et al., 2012).

Desire to eat ratings, however, were positively associated with desires for sweet high-carbohydrate meal items, and were negatively associated with sweet high-carbohydrate snack items. Taken together, considering the high correlations between the sweet high-carbohydrate and sweet high-fat meal scales, and on close inspection of the specific food items involved, these findings demonstrate an association for desire to eat with sweet food items that are high carbohydrate and high in fat, such as cakes and desserts, rather than foods that are high only in carbohydrate, such as fruit and candy. These findings suggest desire to eat to be a motivational construct associated with anticipated pleasure and reward, alongside biological benefit (Berridge et al., 2010; Kenny, 2011), a finding that is also supported in other work (Chmurzynska et al., 2021; Finlayson & Dalton, 2012).

The possibility that these hedonic desires may override homeostatic hunger has also previously been suggested (Kenny, 2011), particularly where the anticipated pleasure from food is high. Indeed, palatability has been proposed as a main driver in food intake decisions in the absence of hunger (Johnson & Wardle, 2014). Our finding is, thus, of importance. If not properly managed, individual differences and predispositions in palatability perceptions and pleasure processing may promote the overconsumption of sweet high-carbohydrate, high-fat foods (Berridge et al., 2010; Finlayson & Dalton, 2012; Johnson & Wardle, 2014; Kenny, 2011).

The idea that subtle differences in food desires may demonstrate biological state is also an interesting possibility. Taken in the reverse direction, our findings suggest that desires for savoury high-protein foods may demonstrate homeostatic and biological needs, while preferences for sweet high-carbohydrate, high-fat foods may reflect more emotional needs. The demonstration of differing anatomical and functional brain regions involved in hedonic and homeostatic feeding is well established (Rossi & Stuber, 2018), but these differences can be difficult to translate into everyday eating situations (Johnson & Wardle, 2014). Confirmation of our findings in more varied scenarios, and alongside more established protocols would be of interest.

In considering our analyses, however, it is important to note that the reliability of some of our scales was low and our regression models predict only 22–24% variance. The inclusion of additional or other food items in the questionnaire could permit more coherent taste / macronutrient content / consumption context scales, improving the strength of our findings. Indeed, different foods would be needed over time and in different countries, to reflect differences in the food supply. In relation to explanatory power, other factors not investigated in this study will also impact hunger and desire to eat, such as time of day, time since last meal, and emotional state (e.g., Kramer et al., 1992). These factors were not investigated here, given our interest in the associations between interoceptive cues, food taste and macronutrient content, rather than in explaining interoceptive cues *per se,* but additional insight may be gained from investigation of more factors.

Further limitations can also be given. The observational nature of the study does not allow for causal inferences. Additionally, the use of subjective self-reported questionnaire data bears a risk of self-reporting bias and response inconsistencies across different participants due to differences in interpretation. It is important to note however, that we sought specifically to understand the associations between a number of subjective experiences, and sought to mitigate concerns over reliability through use of a large data set. Future research may benefit from additionally incorporating objective biological measures of homeostatic hunger, such as blood glucose or ghrelin levels (Beaulieu & Blundell, 2021; Kenny, 2011), to better understand how subjective ratings and objective measures are connected, but any association or lack of association between subjective and objective measures will not negate findings based solely on subjective experiences. Additional or differing measures of hunger and desire to eat could also be added, as could the investigation of eating behaviours alongside self-reports of food desire. Our sample is also notably composed of young adults, and while interoceptive perceptions may deteriorate with age, we have no reason to believe that the distinction between self-reported hunger and desire to eat, as noted in this study, will vary with age or any other demographic characteristic.

Overall, the findings of this study suggest that although hunger and desire to eat are closely related, they are individual concepts. Furthermore, it is possible to distinguish between them as implied by subtle differences in food desires. Hunger was associated with desires for savoury high-protein food items, while desire to eat was associated with desires for sweet high-carbohydrate, high-fat food items. These findings support previous suggestions that eating behaviour for the majority of the population is driven by both homeostatic needs and hedonic desires, likely based largely on learned associations from previous eating experiences.

## CRediT authorship contribution statement

**Julie Wallis:** Writing – original draft, Writing – review & editing. **Katherine M. Appleton:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – review & editing.

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## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: JW has no competing interests to declare. For research in relation to sweet taste, KMA has previously received research funding from ILSI North America, US; the International Sweeteners Association, BE; Ajinomoto Health and Nutrition North America Inc. US; and a consortium of industry partners composed of the American Beverage Association, Arla Foods, Cargill R&D Centre Europe BVBA, DSM-Firmenich SA, International Sweeteners Association, SinoSweet Co., Ltd., Cosun Nutrition Center and Unilever Foods Innovation Centre Wageningen. KMA has also previously received research funding from and has current funding from The Coca Cola Company, US, and has received speaker's expenses from EatWell Global, PepsiCo, US and SEVA (The Hellenic Soft Drinks Industry Association), Greece.

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### *Data sharing*

Data are available from the corresponding author on reasonable request and will be deposited in BORDaR – Bournemouth University's Online Research Data Repository, on acceptance for publication.

### *Declaration of Generative AI or AI-assisted technologies in the writing process*

None used.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2026.105901.

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