The Influence of Body Mass Index on Sweet Taste Preference in Women

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Abstract

Associations between sweet taste preferences and eating behaviour variables may exist with differences in taste preferences evident with varying body mass index (BMI). However, the strength of influence BMI exerts remains unknown, therefore the aim was to examine the influence of BMI on sweet taste preference in women. Three areas were examined, 1) associations between preferences for sweet taste and sweet/fat combinations and eating behaviours, 2) the differences in sweet taste preferences between overweight and lean women, and 3) whether BMI serves as a moderator for the associations between sweet taste preferences and eating behaviour variables.

86 overweight or lean women provided 7day 24hour recall food diaries before attending a laboratory assessment day. Participants completed the Leeds Food Preference Questionnaire (LFPQ) before consuming an *ad libitum* meal consisting of sweet and savoury foods. Immediately following consumption participants completed VAS ratings of palatability and taste intensity in response to the test meal foods.

Sweet taste preferences were associated with an elevated sweet food intake in an *ad libitum* meal and preferences for sweet/fat combinations with habitual dietary fat intake. There were no between group differences on any measure. However, there were differences between groups in a small number of associations between taste preferences and eating behaviour variables which were moderated by BMI.

The present thesis concluded that overweight and lean women did not differ in their sweet taste preferences or eating behaviours. Although, differences in the associations between taste preference and eating behaviours do exist between overweight and lean women. Future work may wish to consider using direct measures of adiposity within the moderation model. These findings build on previous literature through examination of different components of sweet taste preference and

investigates the extent to which BMI moderates differences in the associations with food intake.

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Abbreviations

- BMI = body mass index
- EE = energy expenditure
- EI = energy intake
- EL = explicit liking
- EW = explicit wanting
- FM = fat mass
- FFM = fat free mass
- FFQ = food frequency questionnaire
- GEM = gas exchange monitor
- HFSA = high fat savoury
- HFSW = high fat sweet
- IW = implicit wanting
- LFPQ = Leeds Food Preference Questionnaire
- LFSA = low fat savoury
- LFSW = low fat sweet
- LSG = laparascopic sleeve gastrectomy
- RYGB – Roux-en-Y-gastric bypass
- SSB = sugar sweetened beverages
- TEI = total energy intake
- %BF = percentage body fat

Chapter 1 Introduction and literature review

1.1 Obesity and the obesogenic environment

The World Health Organisation (WHO) estimated that the worldwide prevalence of obesity has almost tripled since 1975, with approximately 39% of the world's adult population now described as overweight (25 kg/m^2 ≤ body mass index (BMI) < 30 kg/m^2) and 13% as obese (BMI ≥ 30 kg/m^2) (World Health Organisation, 2017). Specifically, 26% of UK adults are described as obese, contributing to 617 thousand hospital admissions annually (NHS Digital, 2018). Obesity increases the risk of specific cancers such as colorectal cancer (Liu et al., 2019), breast cancer and pancreatic cancer amongst others (Nimptsch, & Pischon, 2015) and lowers overall life expectancy (Whitlock et al., 2009). Now termed a global epidemic, obesity is a clear public health concern (World Health Organisation, 2014); with genetic evidence capable of explaining differences at an individual level, but failing to adequately explain the rapid upward trends in obesity prevalence at the population level over the last few decades (Wardle, Carnell, Haworth, & Plomin, 2008). This adds pressure onto researchers to better understand the motivational basis of eating behaviour as its dysregulation leads to excess intake and weight gain (Mela, 2006). This has been deemed critical for a better understanding of the necessary components needed to develop prevention techniques (Kirk, Penney, & McHugh, 2010), as it is more economically viable to prevent rather than to treat the associated metabolic disorders and health ailments (Lawlor & Chaturvedi, 2006).

It is accepted that obesity is caused by a chronic caloric surplus, whereby energy intake (EI) surpasses energy expenditure (EE). This is consistent with The First Law of Thermodynamics which relates to the conservation of energy and when applied to human energy balance it can describe the consequences associated with a state of imbalance – when EI is greater than EE there will be an increase in body fat stores (George, Bray, Paeratakul, & Popkin, 2004). This is depicted in the energy balance equation (Figure 1.1). Unfortunately, the First Law is not designed to explain how we regulate food intake; it is a simplification of a multifaceted issue, focusing on energy regulation from a purely numerical viewpoint. It does not consider the complexity of food intake that is nutritional composition, palatability, social circumstances, lifestyle or genetic contributions.

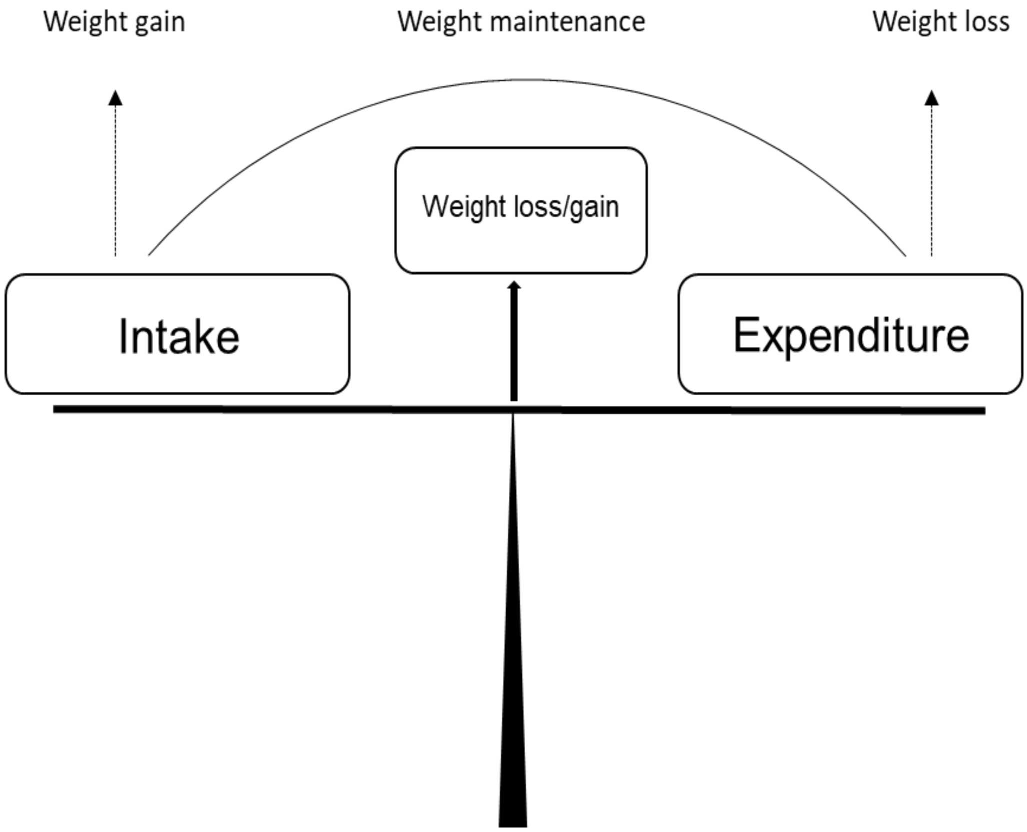

Figure 1.1 Energy balance equation.

Sedentary lifestyles and declining physical activity levels have been postulated as a driver of current obesity rates (Chaput, Klingenberg, Astrup, & Sjödin, 2011; Church et al., 2011). In a North American sample the percentage of individuals characterised as living a sedentary lifestyle has remained relatively stable (Heini & Weinsier, 1997) and in a North American and European sample there has been no observable decline in physical activity related EE (Westerterp & Speakman, 2008). This suggests the food environment we currently live in is in large part responsible for the worldwide increase in obesity rates (Jéquier, 2002). Physical activity and dietary needs for any living organism are in part genetically determined (Simopoulos, 2002). Consequently, changes that have occurred to the food environment and the manner in which we gather food, following the Neolithic and Industrial Revolutions are too recent on an evolutionary time scale for the human genome to adequately adapt (Carrera-Bastos, Fontes, O'Keefe, Lindeberg, & Cordain, 2011).

The abundance of highly palatable and energy-dense foods and increased exposure to food cues has been termed an obesogenic environment (Swinburn, Egger, & Raza, 1999) and is particularly prevalent within Western societies (Sample, Martin, Jones, Hargrave, & Davidson, 2015). Food intake in this environment can become elevated due to increasing energy density of foods, portion sizes and frequency of eating, with both rising in parallel to obesity rates (Ledikwe, Ello-Martin, & Rolls, 2005). A Western dietary pattern is characterised by intake of energy-dense foods, rich in saturated fat, salt and sugar (Bell, Kremer, Magarey, & Swinburn, 2005; Howard et al., 2011). Population level studies in China have identified increasing obesity rates with an increase in Western-style fast food consumption – indicating that as the obesogenic food environment characteristic of Western society spreads to other countries, obesity rates display a linear increase also (Wang, Wang, Xue, & Qu, 2016). Additionally, the level of variety within the diet may also be a risk factor contributing to excess EI - particularly when energy dense foods contribute a large proportion of total energy intake (TEI) (McCrory et al., 1999). This is problematic as a typical modern Western diet includes a large number of energy-dense foods such as sweetened desserts and/or beverages (Bates et al., 2014).

1.1.1 Dietary aspects of obesity risk

Western diets are associated with a higher prevalence of overweight and obesity (Murtaugh et al., 2007) with a greater weight increase in women than men (Schulze, Fung, Manson, Willett, & Hu, 2006). Typical Western diets consist of high levels of simple carbohydrates/sugar and saturated fatty acids (Cordain et al., 2005), paralleled by a reduction in complex carbohydrates, fibre and fruit and vegetable consumption (Nielsen, Siega-Riz, & Popkin, 2002). Previously, sugar and saturated fat intake were restricted due to low availability, however advances in technology have now provided a much greater availability in the current food environment (Cordain et al., 2002; Cordain et al., 2005). A key change is the increase in fast food outlets (Reardon, Timmer, Barrett, & Berdegue, 2003) which enables easy access to energy-dense and highly palatable foods characteristic of a Western diet (Stender, Dyerberg, & Astrup, 2007). The elevated intake of both sugar and fat (Manzel et al., 2014) is problematic as increased sugar intake has been associated with obesity rates (Elliott, Keim, Stern, Teff, & Havel, 2002; Howard & Wylie-Rosett, 2002; Malik & Hu, 2012) as is increased dietary fat intake (Gray & Popkin, 1998).

Brain regions involved in the regulation of energy intake include the hypothalamus, hippocampus (Davidson, Kanoski, Schier, Clegg, & Benoit, 2007) and prefrontal cortex. There is also evidence to suggest that a high fat sweet (HFSW) diet negatively impacts these brain regions (Francis & Stevenson, 2013). This creates a "vicious cycle" whereby a HFSW diet disrupts energy regulation mechanisms within these brain regions, leading to increases in food consumption. This cyclical process is depicted in Figure 1.2.

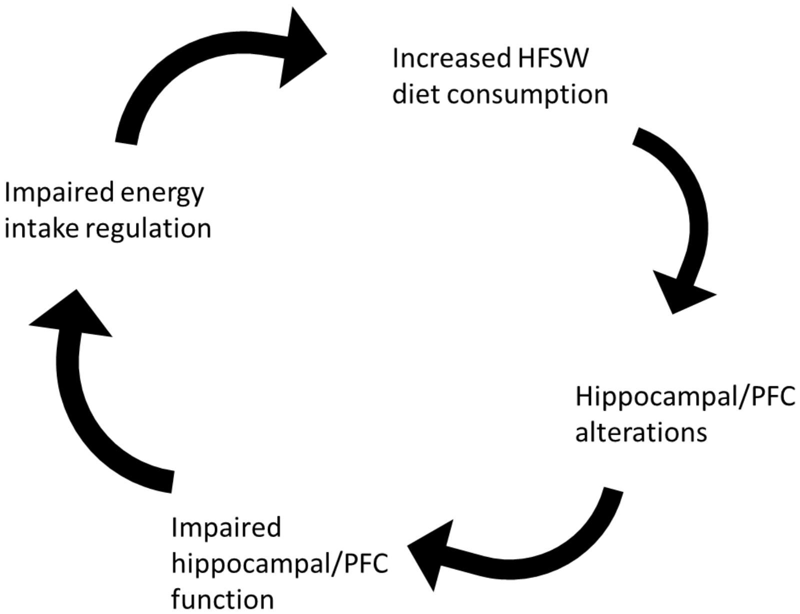

Figure 1.2 The "Vicious circle" model of obesity originally proposed by Davidson (2005) and adapted by Francis & Stevenson (2013).

1.2 The neurobiology of sweet taste

Sweet taste is detected initially within the oral cavity during food consumption via activation of T1R2 and T1R3 taste receptors (Nelson et al., 2001; Zhao et al., 2003). Sweet taste receptors are located not only within the mouth but also areas such as the gut and pancreas (Margolskee et al., 2007; Sclafani, 2007) and more recently have been detected in the hypothalamus (Kohno, 2017). Sweet taste is indicative of an ample energy source, primarily through carbohydrates and exists as an innate preference in humans (Tan & Tucker, 2019). Sweet taste is highly rewarding, as characterised by a universal liking for sweetness in foods and beverages in infants (Ventura & Mennella, 2011) and can beneficially alter mood in healthy participants (Kampov-Polevoy, Alterman, Khalitov, & Garbutt, 2006). Moreover, sweet taste preferences appear stronger whilst an individual is young and demonstrates a natural age-related decline (Desor & Beauchamp, 1987; Yoshinaka et al., 2016).

Upon detection of a sweet tasting substance, dopaminergic pathways within the brain are activated which are responsible for the hedonic drive; this results in dopamine release in the nucleus accumbens in laboratory animals (Bassareo & Di Chiara, 1999) and the dorsal striatum in humans (Small, Jones-Gotman, & Dagher, 2003). However, although sweetness alone may result in a hedonic response (Westwater, Fletcher, & Ziauddeen, 2016), when coupled with energy density (calories) this response is greater. For instance, sucrose, a caloric sweet sugar, is known to activate the brain's reward circuitry whereas sucralose, a non-nutritive sweetener, does not have the same strength of response (Frank et al., 2008).This supports the claim that a match between energy load and sweetness intensity interacts to develop a more potent hedonic response (Veldhuizen et al., 2017).

Furthermore, the neural circuitry that is activated by sweet tasting stimuli in the presence of energy density overlaps with the circuitry activated via drugs of abuse (Drewnowski, Krahn, Demitrack, Nairn & Gosnell, 1995), highlighting the strength of the stimuli's rewarding characteristics. Qualitative insights into so-called 'food addiction' have identified self-perceived food addicts are characterised by an elevated body weight and increased reward-driven eating, amongst other characteristics (Ruddock, Dickson, Field, & Hardman, 2015). Similarly, an early study examining 'chocolate addicts' noted elevated levels of arousal, cravings and negative affect in the presence of chocolate – patterns similar to those observed in individuals with substance abuse addictions (Tuomisto et al., 1999). However, this is not to suggest that sweet taste preference and addictive behaviours are equivalent (Finlayson, 2017; Drewnowski & Bellisle, 2007).

1.3 Sweet taste and food intake

The powerful hedonic drive towards sweet taste and its associated energy have been proposed as an important contributor towards excess weight gain (Te Morenga, Mallard, & Mann, 2012). Sweet taste preference is associated with an increased intake of carbohydrates (Drewnowski, Henderson, Levine, & Hann, 1999) and animal models have shown feeding behaviours increase following a high sugar diet (May et al., 2019). This suggests that it remains possible for current intake to influence future eating behaviours, and associations present between sweet taste preference and eating behaviour may be an example of reverse causation. Moreover, a prospective study showed that the hedonic response to sweet taste may predict weight gain at 5 year follow up (Salbe, DelParigi, Pratley, Drewnowski, & Tataranni, 2004). Therefore, 'unsweetening' the world's diet has been proposed as one possible solution to the current obesity epidemic (Yang, 2010). However, when in an energy deficit the subjective pleasantness of a sweet taste increases which can in turn be a driver for sweet food intake (Rodin, Moskowitz, & Bray, 1976) a possible reason for failure of weight loss attempts. Differences in sweet taste perception as a function of body weight

Sweet taste preference was for a long time believed to be uninfluenced by body weight with most early available data appearing to support this claim (Wooley, Wooley, & Dunham, 1972). However, improvements in psychophysical measurements have shown this may not be the case (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006). Taste preferences differ within sub-groups of the population when distinguished by sex and weight (van Langeveld et al., 2018). However, the evidence remains inconclusive, with some studies demonstrating an association between liking for fat sensations and BMI (Cox, Hendrie, & Carty, 2016; Deglaire et al., 2015), between liking for salty foods and BMI (Matsushita et al., 2009), or not finding any associations present between BMI and taste preferences (Cox, Perry, Moore, Vallis, & Mela, 1999). Given the incongruent findings, a recent systematic review concluded that due to methodological variations between studies, it is at present challenging to arrive at definitive conclusions (Cox et al., 2016).

Although an association between BMI and sweet taste preference is not always observed, there does exist an association between an elevated BMI and HFSW preferences which is particularly evident in women (Deglaire et al., 2015). Using ‘sniffin sticks’ individuals with obesity/overweight were shown to have distortions to taste and smell perception that was closely linked to visceral fat levels within the body (Fernandez-Garcia et al., 2017). These notable differences are believed to stem from increases in sweet taste thresholds – requiring stronger concentrations of stimuli - that are associated with an elevated level of adiposity within the body (Donaldson, Bennett, Baic, & Melichar, 2009). Using taste strips to investigate this relationship, it was established that a general lowering of taste sensitivity occurs with an increase in BMI (Vignini et al., 2019). Lean individuals relative to overweight or obese individuals present with a higher sweet taste sensitivity – requiring smaller quantities and weaker concentrations – which in some instances results in a lower intake in carbohydrates and TEI as well as a lower frequency of sweet food intake (Jayasinghe et al., 2017). Conversely, obese individuals display a lower sweet taste sensitivity and therefore lower perceived intensity, despite a higher liking (Donaldson et al., 2009). With the inclusion of fat to a stimulus, the sweetness intensity remains unchanged but the palatability of the stimulus increases (Bolhuis et al., 2018; Drewnowski et al., 1992). In this way the sensitivity to taste may impact subsequent preferences and intake, leading to a positive association between BMI and HFSW food preference.

1.3.1 Sweet and fat preference

The WHO’s definition of ‘free sugars’ includes any sugar added to a food product during the manufacturing process, plus those naturally occurring in honey, syrups and fruit juices (WHO, 2015). There is little evidence that has examined the deleterious effects of general free sugar or total sugar intake (Ahmad, Mok, Rangan, & Louie, 2019), although sugar sweetened beverages (SSB) have consistently been demonstrated to be causally linked to the epidemiology of obesity (Hu, 2013). Sugar within food serves to increase the sweet taste, therefore sugar intake within the diet may provide an indication of sweet food intake. The sweet taste is principally produced by sugars - a sweet-tasting, soluble carbohydrate made up primarily of monosaccharides and disaccharides - and a small amount of other substances such as non-caloric or artificial sweeteners (Lim & Pullicin, 2019). Therefore, a diet characterised by high intakes of sugar may be indicative of a diet also characterised by intensely sweet tasting foods.

There has previously been uncertainty expressed as to whether obesity, is directly caused by excess sugar intake, or the associated excess EI (Kahn & Sievenpiper, 2014). Recently it was highlighted that an increase in sugar consumption of 20% is associated with an increase mortality risk of approximately 30%, and a lower sugar consumption is associated with overall better dietary choices (Ramne et al., 2018). In the UK total sugar intake is on average 20% of TEI, with free sugars contributing 11.4% of TEI – indicating that a large proportion of the population exhibit an intake higher than the government’s recommendation of <5% (Azaïs-Braesco, Sluik, Maillot, Kok, & Moreno, 2017). Moreover, inclusion of one 350-ml serving of a SSB containing around 40-50g of sugar and 150kcal, without the subsequent reduction of calories from other sources, has the propensity to lead to weight gain of over 6kg in one year (Apovian, 2004). However, this is assuming a ‘static model for weight loss’ which might not fully reflect actual mechanisms of weight change and consequently may overestimate weight gain (Scheelbeek, Cornelsen, Marteau, Jebb, & Smith, 2019). Despite this, when holding EI constant there is no difference in weight change with varying sugar intakes (Te Morenga et al., 2012). The relationship between SSB intake and obesity is shown consistently throughout the available literature (Chen et al., 2009; Hu, 2013; Tahmassebi & BaniHani, 2019) and when considering available evidence that indicates a weaker satiating effect of energy obtained through liquid relative to solid products (Almiron-Roig et al., 2013), this relationship may seem intuitive. These findings suggest that it is not the inclusion of sugar *per se* that creates weight gain, rather the predilection to contribute to an energy surplus that is detrimental, and evidence shows that sugar consumption is capable of facilitating this energy surplus.

'Fat' is the term used to refer to naturally occurring triglycerides (Liu, Archer, Duesing, Hannan, & Keast, 2016) and is proposed as a driver for weight gain, following the observation that overweight individuals obtain a larger proportion of their dietary intake from sources high in fat (Miller, Lindeman, Wallace, & Niederpruem, 1990). Fat contains 9kcal/g and is regarded as the least satiating macronutrient (Blundell & MacDiarmid, 1997), thereby easily facilitating passive overconsumption – defined as a passive form of high consumption of dietary fat rather than eating as actively driven (Blundell & Macdiarmid, 1997).

An elevated BMI is associated with a greater enjoyment of food generally, but there is also an increase in the enjoyment of fat sensations specifically, believed to be directly linked to an individual's percentage body fat (%BF) (Drewnowski, 1997). This is reasoned to be a consequence of reduced taste sensitivity associated with increased adiposity (Altun et al., 2016; Berthoud & Zheng, 2012). When sugar and fat are integrated into a food item, the perception of fat is masked, leaving the perception of the sweet taste unaltered (Bolhuis, Costanzo, & Keast, 2018; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992). Individuals with overweight and obesity exhibit a dislike for sweet solutions absent of fat, although provide favourable ratings with its inclusion (Drewnowski et al., 1985). A similar observation has been reported more recently, concluding that obese women prefer the sensations of fat to the sensations of sweet (Deglaire et al., 2015) and the hypothesis that an elevated body fat is associated with an increased preference for foods characterised as HFSW is proposed.

Moreover, there exists associations between higher free sugar intake in the diet and a higher TEI (Ramne et al., 2018) as well as higher fat intake and TEI (Méjean et al., 2014). Further to this, when sugar and fat are combined in food items, the two produce a highly palatable, energy dense and poorly satiating duo which can easily lead to passive overconsumption (Lucas, 1989).It is therefore important to consider the inclusion of both sugar and fat when investigating sweet taste preference expressions in the diet, particularly their propensity to contribute to an energy surplus.

Both sugar and fat within the diet have been proposed as potential contributors of obesity (Field, Willett, Lissner, & Colditz, 2007), however, focusing on specific components or macronutrients within a diet has not proven fruitful. The Australian-Paradox (Barclay & Brand-Miller, 2011) has shown that over a 30 year period obesity rates increased by approximately 300% whilst sugar intake decreased by 20%. On the other hand, in North America both BMI and obesity rates have increased over a 10 year period whilst fat intake has decreased (Heini & Weinsier, 1997). If the presence of either fat, or sugar, within the diet were to be responsible for the increased rates of obesity, then these incongruent findings would not be observed.

Common dietary advice for those individuals seeking to lose weight has previously consisted of reducing free sugar intake whilst simultaneously reducing levels of fat in the diet (Gibson, 1996). However, this may not be entirely possible; dietary survey data reveals the existence of an inverse association between sugar and fat intake, with historical evidence demonstrating that high sugar consumers are simultaneously low fat consumers and vice versa (Baghurst, Baghurst, & Record, 1994; Blundell &

Macdiarmid, 1997). This association has been termed the ‘sugar-fat seesaw’ (McColl, 1988) and it is hypothesised that in freely chosen diets limiting EI from both fat and sugars simultaneously in order to comply with dietary guidelines may be too difficult to achieve at a population level (Gibney, 1990). It is important to the note that these studies have consisted of self-report techniques, which should be interpreted with caution (Schoeller, 1995); however, most studies examining this phenomena either do not consider under-reporting participants or find no significant effect on the results from their exclusion (Sadler, McNulty, & Gibson, 2015).

Despite decreasing sugar intake being postulated as an effective method for reducing calorie intake and preventing weight gain or contributing towards weight loss (Azaïs-Braesco et al., 2017) the observations of the sugar:fat seesaw suggest that this may not be sufficient. Whilst holding TEI constant, as EI from one macronutrient increases this will inevitably occur at the expense of another macronutrient – likely fat in this instance. In addition to this, FFQ data from the late 1980’s highlighted that large sources of dietary fat are provided by foods that are simultaneously high in free sugars (Drewnowski & Greenwood, 1983). These highly palatable foods (e.g. biscuits, cakes, puddings) provide levels of fat within the diet that may otherwise not be eaten. Sweetened fat has largely been responsible for the increased consumption of carbohydrate rich fat; as fat is introduced to a food the optimum sugar dose is lowered with sweetness intensity remaining unchanged (Bolhuis et al., 2018). Indeed, snack foods high in both sugar and fat are often consumed beyond homeostatic needs (Cleobury & Tapper, 2014). Early survey data examining the associations between high or low fat diets and other macronutrient intakes identified that individuals who habitually consumed a low fat diet did so with an increase in simple sugar intake (Baghurst et al., 1994), thereby reiterating the predictions of the sugar:fat seesaw. Therefore, recommendations to reduce either sugar or fat in the diet may not prove to be effective methods of weight management.

Utilising food preference lists to examine preferences in overweight participants noted the most commonly included foods were characterised as high in fat and carbohydrates (Drewnowski et al., 1992). This supports the notion that fat content does not alter sweetness intensity yet serves to increase palatability (Bolhuis et al., 2018; Drewnowski et al., 1992). Therefore the dominant sensation is that of sweetness and subsequently overweight individuals whilst preferring the sensations of fat and sweet combined, may only identify this as a sweet taste preference, (e.g. stating possession of a sweet tooth because of a preference for chocolate) (Weingarten & Elston, 1991). Building on this conclusion more recently, lean women were shown to exhibit elevated liking for sweet sensations and specifically sweet carbohydrate only foods, whereas overweight women tended towards a preference for the sensations of fat and sweet combined, with perceived sweet intensity associated with subsequent sweet food intake (Jayasinghe et al., 2017). With this evidence a picture emerges suggesting that body weight is closely linked to food palatability, influencing components such as perceived intensity and subjective liking, which in turn influences intake – however a causal relationship is yet to be identified. Given that it has been suggested that free sugars are the vehicle for increased dietary fat intake (Emmett & Heaton, 1995) it is justifiable to predict that there will be a positive association between BMI and preference for HFSW food types.

In a like manner, FFQs have identified the existence of a positive correlation between BMI and fast food intake – foods characterised by simultaneously high levels of both fat and sugar, whilst concurrently sharing an inverse relationship with fruit and vegetable consumption (Schröder, Fïto, & Covas, 2007). This raises concerns that foods characterised as HFSW displace other more nutrient dense foods, particularly given evidence which highlights over 50% of a typical person's diet is made up of HFSW snack foods, fast food or SSB (Martínez Steele et al., 2016). However, these calorie dense foods are often eaten in daily life due to their affordability (Drewnowski, 2007).

The available evidence on sweet and fat preferences has highlighted that isolating components of the diet and focusing on single macronutrient intake is fraught with challenges as intake of one nutrient invariably affects intake of other nutrients. Furthermore, intake of foods that are HFSW is associated with a reduced intake of health promoting foods. As demonstrated with the sugar:fat seesaw, elevated intake of dietary fats occurs at the expense of sugars and carbohydrates, with fat displacing the sugars and vice versa. For this reason, despite the present thesis focusing on sweet taste preferences, there will be consideration of dietary fat intake and the relationship that this holds with BMI, particularly in regards to HFSW taste preferences.

1.3.2 Underlying mechanisms influencing taste preferences

A number of studies examining body weight and taste have focused on taste sensitivity thresholds; the results from these studies are important to consider as sensitivity is capable of subsequently impacting the determination of taste preferences (Akella, Henderson & Drewnowski, 1997; Drewnowski & Henderson, 2001). For example, one study noted that individuals who were highly sensitive to a sucrose solution consumed significantly more non-sweet foods (Han, Keast, & Roura, 2017). It is necessary to consider studies that have examined sweet taste sensitivity, as evidence suggests an association between taste sensitivity and subsequent taste preference.

A compelling, although extreme, population to examine are individuals that have achieved weight loss through surgery, as this enables the identification of influential appetite related hormones. These individuals experience immediate and extreme changes to their taste preferences with marked differences specifically involving sweet taste (Altun et al., 2016). These changes are widely observed, with pre-surgery preferences tending towards foods characterised as HFSW, whereas post-surgery there is shift towards preferences for fruits and less energy dense foods (Andriessen et al., 2018). As many as 94.8% of patients that have undergone laparascopic sleeve gastrectomy (LSG), report an increase in sweet taste sensitivity, whereas 57.4% of

Roux-en-Y gastric bypass (RYGB) patients report a decrease in sweet taste sensitivity (Shoar, Naderan, Shoar, Modukuru, & Mahmoodzadeh, 2019). Following LSG circulating ghrelin levels are elevated whereas following RYGB levels decline – highlighting hormone's important role in the regulation of sweet taste sensitivity and a potential mechanism of action. Interestingly, these changes in sensitivity are reflected in the patient's food intake patterns following surgery, with previously enjoyed foods that are HFSW causing postprandial discomfort (Nielson et al., 2019).

Moreover, in mice leptin is a sweet taste suppressor (Kawai, Sugimoto, Nakashima, Miura, & Ninomiya, 2000; Shigemura et al., 2004). Adipose cells produce leptin in order to regulate food intake; through inhibition of gustatory responses to sweet substances (Nakamura et al., 2008). According to the lipostatic hypothesis, FM is the primary driver of EI, with the leptin released in direct proportion to the amount of FM within the body. This creates a negative feedback loop, whereby elevated serum leptin levels inhibit ingestive behaviours, in an attempt to maintain optimal fat levels within the body (Zhang, Proenca, Maffei, Barone, & Leopold, 1994). This communication occurs via the hypothalamus and has been demonstrated to be influential in the role of sweet taste thresholds (Berthoud & Zheng, 2012; Umabiki et al., 2010). For this reason, it is reasonable to surmise that the chronically increased serum leptin levels in obese patients caused by the increased adiposity within the body are another potential contributor to the decreased sweet taste sensitivity.

1.3.3 Sweet taste expression within eating behaviours

Available literature indicates a higher sugar consumption is associated with an increased risk of type 2 diabetes and obesity (Guasch-Ferré & Hu, 2019; Hu, 2013). However, longitudinal data available via French populations has indicated that an increased intake of sugar is associated with a decreased risk of obesity (Lampuré et al., 2016) and type 2 diabetes (Lampuré et al., 2019). Upon further exploration of the sources of sugar within the diet, it was identified that this inverse association was primarily driven by a preference for 'natural sweetness', which was also associated with an increased intake of fruits and vegetables as well as wholegrains whereas a preference for HFSW foods was positively associated with obesity risk (Lampuré et al., 2016) and diabetes risk (Lampuré et al., 2019). This led to the conclusion that it is not necessarily the inclusion of foods high in sugar that displaces other nutritionally dense foods within the diet, rather the inclusion of free sugars and dietary fats that are easily digested and poorly satiating, expanding on and supporting previous work (Emmett & Heaton, 1995; Kant, 2000; Marriott, Olsho, Hadden, & Connor, 2010; Martínez Steele et al., 2016).

The available evidence supports the idea that it may not be a sweet taste preference *per se* that predisposes individuals to weight gain and obesity; it may be the expression of this sweet taste preference that is of more importance. A sweet preference may not be a contributor to excess EI and weight gain if this preference is expressed through low calorie and nutrient dense options such as fruit and vegetables. It appears that a sweet preference is capable of becoming a contributor to obesity and negative health related outcomes when it is expressed via free sugar and HFSW foods intake.

1.4 Processes involved in sweet food reward

There exists a distinction between homeostatic hunger (driven by nutritional demands) and hedonic hunger (reward-driven eating) – often termed non-homeostatic hunger. Hedonic hunger operates beyond the necessity to negate energy depletion (Lowe & Levine, 2005) with a number mechanisms involved in appetite control; the major components include food palatability, food reward and eating behaviour traits (Berthoud & Zheng, 2012). It has been established that hedonic thoughts relating to food and the sensory appreciation of certain food attributes such as sugar and fat determine food preferences and choice, thereby contributing to meal size and frequency (Dalton and Finlayson 2013).

Recent contemporary models of appetite control have included higher level cognitive functions such as learning, memory or attention (Higgs et al., 2017). As an example, it has been shown that focusing on the long term health outcomes associated with eating unhealthy foods is associated with the inhibition of reward-related brain activity (Hare, Camerer, & Rangel, 2009). Including cognition in a model of food reward is not to suggest that we consciously consider food decisions at all times, the majority of the time eating behaviours are ‘mindless’ (Herman & Polivy, 2014). Cognitive processes involved in eating a meal include the expectations associated with the food (involving memory and attention), the pleasantness and reward whilst eating the meal (attention and cognitive control) and finally a memory of the meal (Higgs et al., 2017). In this way eating behaviours and taste preferences are influenced to an extent by underlying cognitive factors as well as homeostatic and hedonic influences.

1.4.1 Food reward

It has been suggested that in the current obesogenic environment, in which readily available palatable and energy dense foods are easily accessible, mechanisms of reward originally designed to increase ingestion are no longer an asset (Olszewski, Wood, Klockars, & Levine, 2019). Food, and particularly sweet tasting food, is hard wired to be intrinsically rewarding in nature (Steiner, 1973), with early data suggesting a physiological role of pleasure that is regulated by body weight (Thompson, Moskowitz, & Campbell, 1976).

Two core processes are involved in food reward and by extension, the expression of taste preferences; the concepts of ‘liking’ and ‘wanting’ (Berridge & Robinson, 2003) are believed to be distinct yet closely related components. The conceptualisation of liking and wanting as psychological constructs within the present thesis is based upon the definition provided by Finlayson and colleagues (e.g. Finlayson & Dalton, 2012).

In addition to liking and wanting, a hypothetical construct, ‘palatability’ also contributes to food intake. Palatability was previously suggested to reflect underlying biological needs for a nutrient, e.g. the palatability of sweet tastes when hungry can be interpreted as an expression of energy requirements (Cabanac, 1989). On the other hand, palatability has also been suggested to relate to reward processes. However, an integration of the two has been proposed, with palatability suggested to act to promote intake through a hedonic system with inputs from systems regulating needs (Yeomans et al., 2004). It has previously been demonstrated that palatable unhealthy foods are preferred over less palatable foods (Craeynest, Crombez, Haerens, & De Bourdeaudhuij, 2007) with a common neural substrate mediating both the palatability and the reward value of foods (Wassum, Ostlund, Maidment, & Balleine, 2009). In this way, the palatability of a food is linked to the reward provided by its ingestion.

1.4.1.1 Liking

Liking can be viewed as the perceived hedonic value of a food (imagined or experienced), the appreciation of its sensory qualities or the subjective judgement of the degree of pleasure that consumption elicits. It is possible for liking to be influenced by an individual's hunger state such as when satiated (Small, 2001) or fasted (Cameron, Goldfield, Finlayson, Blundell, & Doucet, 2014a) and has been suggested to be the most consistent predictor of food consumption (Cox et al., 2016).

1.4.1.2 Wanting

'Wanting' is defined as the motivational attraction toward or craving triggered by a food cue or related food cues. This implies a target food (or food category) and a greater degree of variation is present with factors such as hunger (Small, 2001) or the quality and duration of the previous night's sleep (Benedict et al., 2012) amongst others, capable of impacting the degree of wanting. Wanting can be initially broad – such as when food deprived and wanting indiscriminately increases independently of BMI (Castellanos et al., 2009), or alternatively, it is possible to be rather narrow or focused, such as a drive for specific macronutrients when in a state of imbalance (Griffioen-Roose, Mars, et al., 2012).

1.4.1.3 Implicit and explicit components

The subjective sensations of liking and wanting are distinct but share a certain amount of overlap, with both liking and wanting responses to food cues capable of occurring with or without conscious control, displaying an explicit and implicit element. A visual representation of the different components contributing to food reward can be seen in Figure 1.3. Explicit liking (EL) is the perceived or anticipated hedonic reaction from a tasted food whilst explicit wanting (EW) is the subjective desire for a perceived food. Implicit wanting (IW), derived from the concept ‘incentive salience attribution’, is the unconscious motivation to eat one food over another (Finlayson, King, & Blundell, 2007). To highlight that the processes are separate, one study in which healthy participants ate chocolate beyond satiation demonstrated a greater degree of and faster decline in subjective ratings of wanting than ratings for liking (Small, 2001). Indeed liking and wanting have been referred to as ‘go systems’ (Berridge, Ho, Richard, & DiFeliceantonio, 2010) in which liking can be diminished by satiety signals but cannot be shut off and halt intake entirely. This illustrates the manner in which it is possible for liking to be present even in the absence of EW.

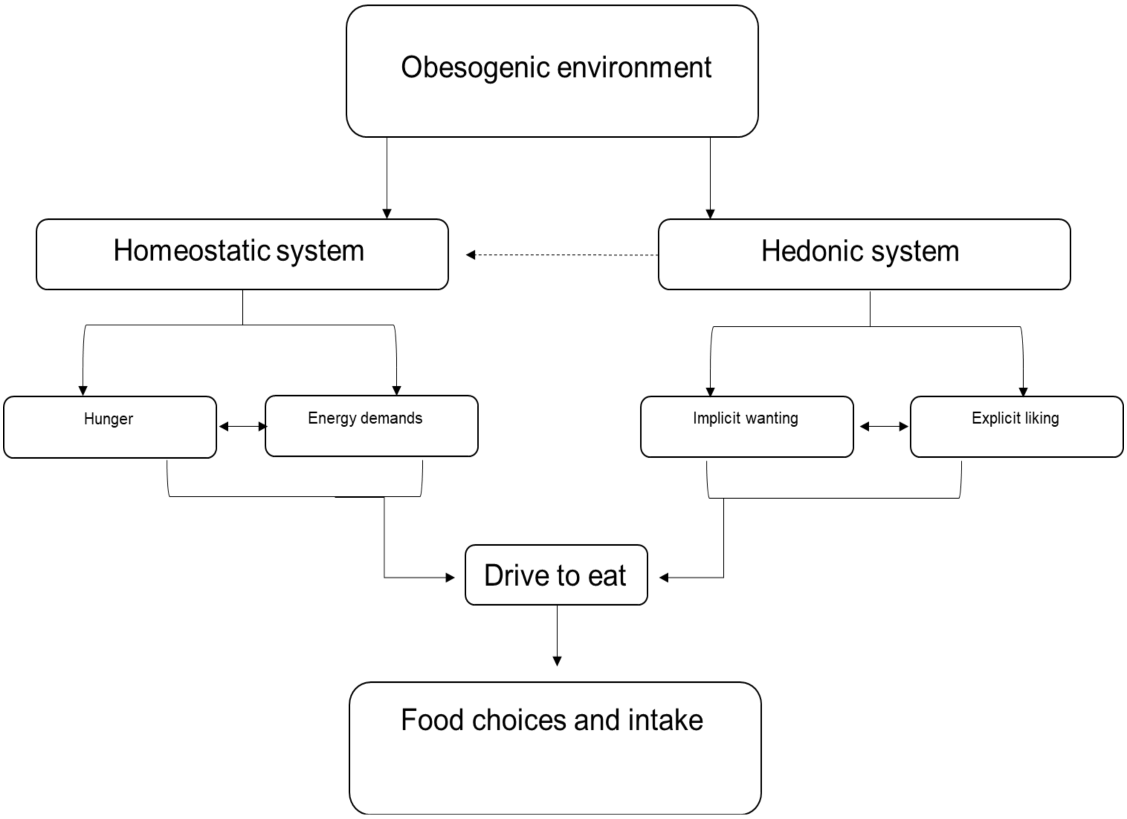

Figure 1.3 Visualisation of food reward.

1.4.1.4 Food reward and body weight

Food is a powerful reinforcer, although this power differs between individuals with varying body weight and the available evidence suggests that an individual's sensitivity to reward is capable of indirectly influencing their BMI (Davis, Patte, Levitan, Reid, Tweed, & Curtis, 2007). Saelens and Epstein (1996) illustrated that obese women are more susceptible to the reinforcing effects of food compared to non-food rewards - demonstrated by an increased willingness to work for food rewards in a computer based task. This finding highlights that as body weight increases, individuals exhibit a higher degree of IW with a higher drive and motivation for food rewards. This is reasoned to be due to increased activity in regions of the brain that process palatability which leads to obese individuals favouring food over alternative reinforcers (Volkow, Wang, & Baler, 2011). Review of these processes has shown that implicit measures of wanting are a more valuable measure for highlighting differences in food reward between obese and lean individuals than explicit measures, as explicit measures may be more susceptible to the effects of demand characteristics of social desirability bias in a laboratory environment (Mela, 2006). This is due to the proposition that obese subjects possess a greater motivation for food consumption which is directed towards energy dense foods; despite no difference in the subjective pleasure derived from the orosensory experience of eating (Mela, 2006). Furthermore, there are notable differences in liking and wanting specifically towards HFSW stimuli in overweight and obese participants (Nijs, Muris, Euser, & Franken, 2010).

With this available evidence considered, that sweet or fat foods, or a combination of the two are regarded as rewarding in their nature, it is reasonable to suggest that individuals who are more likely to be sensitive to food reward (those with an elevated BMI) are simultaneously more likely to be susceptible to the rewarding properties of these food types. For this reason it may be hypothesised that participants with an elevated BMI will display higher scores for implicit compared to explicit components of food reward.

1.4.1.5 Food palatability

Palatability constitutes the sensory properties of foods (primarily taste and smell) (Johnson & Wardle, 2014) and is similar to liking in that it relates to the hedonic reward provided by foods (Friedman & Stricker, 1976), although differs in that it is a more global enduring concept. There is evidence to suggest that hunger and palatability work independently to determine intake and a clear distinction between the pleasantness of the taste of a food (influenced by palatability) and the pleasantness of ingesting said food (influenced by hunger) should be made (Rogers, 1990).

Foods that are of a higher palatability are ingested more easily and lead to a higher EI which is not reflected in higher levels of fullness or decreases in hunger (Yeomans & Symes, 1999). Subsequently palatable foods may make it easier to overconsume and create a calorie surplus. There is a reliable body of evidence to suggest that greater palatability increases EI on a short-term basis in a causal manner (Johnson & Wardle,

2014) and obese participants find eating palatable food more reinforcing than do non-obese counterparts (Saelens & Epstein, 1996).

Available data provided via free living studies reports that 77% of meals consumed are rated as palatable, with nutritional concerns less relevant (de Castro, 2000) and in addition to this, it is possible to predict the likelihood of overeating based on the number of palatable foods in the surrounding environment (Thomas, Doshi, Crosby, & Lowe, 2011). In this way palatability is influential in the formation of taste preferences and impacts eating behaviour.

A number of variables impact a food's perceived palatability - including macronutrient composition, with foods higher in sugar/carbohydrates and fat generally being perceived as more palatable (Small & DiFeliceantonio, 2019). Palatability is such a strong driver in informing our food choices that it overcomes other powerful drives such as social influences (Pliner & Mann, 2004). However, it is important to note that it is not palatability of food *per se* that contributes to overconsumption, rather it is the high energy density associated with commonly palatable foods that are rich in fat and sugar that is enabling overconsumption (Mela, 2006).

Palatability therefore, although very similar to liking in that it relates to the hedonic value of a food item, is not synonymous. Liking may be viewed as the sensory pleasure to a food item at that specific moment in time (Oustric, Gibbons, Beaulieu, Blundell, & Finlayson, 2018), whereas palatability is determined by the interaction of oro-sensory and post-ingestive characteristics intrinsic to the food itself (Rogers, 1990). Within the present thesis, palatability ratings were provided in response to the experience of ingesting a real food whereas liking was perceived pleasure elicited by the experience of tasting a food.

Current evidence therefore suggests that taste preferences will be correlated with eating behaviours. It is also suggested that taste preferences differ between individuals defined with overweight or obese and lean using BMI. However, the exact influence that BMI exerts over these associations remains unclear. Therefore the present thesis will attempt to address this issue by examining the moderating influence that BMI exerts over the association between taste preferences and eating behaviour variables.

1.5 Aims and hypotheses

The present thesis will investigate three main issues; 1) the relationship between sweet taste preference (EL, EW and IW) for sweet or sweet/fat combinations and eating behaviours, 2) the role of BMI on sweet taste preference and 3) the role of BMI as a moderator of the relationship between sweet taste preference and eating behaviour variables.

1.5.1 What is the relationship between sweet taste preference for sweet or sweet/fat combinations and eating behaviours?

To examine the relationship between sweet taste preference for sweet and sweet/fat combinations and eating behaviours the associations between sweet taste preferences (LFPQ) and eating behaviour outcomes (*ad libitum* intake of sweet, savoury a total food, test meal palatability ratings for ‘liking’, ‘intensity’ and ‘pleasantness’ in response to a sweet and savoury food and habitual intake of sugar, fat and TEI) will be examined.

Hypotheses;

- Higher sweet taste preference will be associated with higher intake of a sweet food item in an *ad libitum* test meal.
- Higher sweet taste preference will be associated with higher palatability ratings to a sweet food in a test meal.
- Higher HFSW taste preference will be associated with a higher intake of both sugar and fat in the habitual diet.
- Higher sweet taste preference will be associated with a higher intake of sugar in the habitual diet.

1.5.2 What is the role of BMI on sweet taste preference?

To examine the role of BMI of sweet taste preferences, independent *t*-tests will be conducted examining differences between overweight and lean groups for LFPQ taste preferences, *ad libitum* intake of a sweet, savoury and total food, test meal palatability and intensity responses to a sweet and savoury food item and habitual dietary intake.

Hypotheses;

- There will be no between groups difference in EL, EW or IW sweet bias scores.
- Overweight participants will display higher preferences for high fat sweet foods (HFSW) than lean participants.
- The percentage intake of sweet food in a low fat meal consisting of sweet and savoury components will be higher in lean participants than overweight.
- Overweight participants will display a lower sweet taste sensitivity than lean participants.
- Overweight participants will report a greater portion of their free-living energy intake from fat, while lean individuals will obtain a greater proportion of their energy intake from carbohydrate/sugar.

1.5.3 Does BMI act as a moderator of the relationship between sweet taste preference and eating behaviour variables?

The role of BMI on sweet taste preference will be examined via associations between taste preferences and eating behaviour variables in overweight and lean groups separately. Taste preferences will be assessed via the LFPQ with eating behaviour variables including *ad libitum* intake of sweet, savoury a total food, test meal palatability ratings for 'liking', 'intensity' and 'pleasantness' in response to a sweet and savoury food and habitual intake of sugar, fat and TEI. Formal moderation analysis will be performed where any statistically significant association ($p \leq .05$) is present in either or both groups for a sweet taste preference with a theoretically relevant eating behaviour.

Hypotheses;

- Associations between EL, EW and IW sweet bias scores and *ad libitum* intake of a sweet, savoury and total food will be moderated by BMI, with a stronger positive association at higher levels of BMI.
- Associations between EL, EW and IW sweet bias scores and test meal palatability ratings of a sweet and savoury food items will be moderated by BMI, with a stronger positive association between sweet palatability at lower levels of BMI, and a stronger positive association between savoury palatability at higher levels of BMI.
- Differences between EL, EW and IW sweet bias scores and habitual intake of sugar, fat and TEI will be moderated by BMI, with a stronger positive association between fat intake at higher levels of BMI.
- The will be a positive association between HFSW preferences and habitual sugar and fat intake in overweight but not lean participants.

Chapter 2 Methodology

The study protocol described herein was conducted within the remit of a wider research project (Diet-Induced Variability in Appetite - DIVA study, ClinicalTrials.gov reference: NCT03447600) and consequently participants completed a number of measures otherwise unreported. Only measures and procedures that are relevant to the pertinent research questions previously outlined are reported.

2.1 Design

A cross-sectional, between-subjects design was employed with two separate groups established, determined on the basis of BMI (see table 2.1). An initial screening questionnaire (see Appendix 1) established participant eligibility, with those eligible invited to attend a pre-screening session at the Human Appetite Research Unit (HARU) at the University of Leeds (visit 1). Following this initial lab visit participants completed 7 days of 24hour food diaires before returning to the lab for their assessment day (visit 2). During the assessment day, anthropometric, body composition and resting metabolic rate were measured, and participants completed the LFPQ prior to an *ad libitum* test meal 2 hours 45 minutes following consumption of a standardised breakfast meal and provided subjective palatability and intensity ratings to a sweet and savoury food items.

2.2 Procedure

All participants were screened prior to their enrolment in the study. The study was described as investigating the impact of health behaviours on mood in women, all participants received a full debrief upon completion of the study. Participants were shown the images used within the LFPQ and offered alternative images for any foods that would not ordinarily be freely chosen to consume, how to use MyFood24 and how to complete visual analogue scale (VAS) questionnaires. The study investigated preferences for sweet and sweet/fat combinations in female participants only and not male participants, due in part, to evidence demonstrating that male participants display preferences for salt, umami or savoury tastes (van Langeveld et al., 2018).It was anticipated that observable differences between BMI groups in sweet taste preferences and their manifestation in eating behaviours would be greater in females than in males – who would be expected to display preferences towards different tastes.

Participants arrived at the HARU after completing an overnight fast, avoiding strenuous physical activity or exercise and alcohol for 24 hours prior as well as any sources of caffeine for 12 hours prior. Body composition was measured using air displacement plethysmography (Bodpod, Concord, USA)) before RMR was measured using indirect calorimetry (GEM Nutrition, Cheshire, UK). Following these two measures participants were provided with a standardised breakfast calculated at 25% of RMR. Breakfast start time was noted, and once the breakfast meal was completely ingested participants were instructed to return to the HARU exactly 2 hours 45 minutes later. This ensured that breakfast and lunch meal initiation were as close as possible to being 3 hours apart. During this period participants were instructed to refrain from eating or drinking anything, with the exception of a bottle of water provided by the researcher.

The second session of the assessment day began with the LFPQ for lunch food items and a VAS questionnaire. Once these were completed the lunch meal was provided and following meal cessation participants completed a test meal palatability VAS .

Following this the participants were free to leave the HARU and their participation in the study was completed. The order of the assessment day protocol can be seen in Figure 2.1 below.

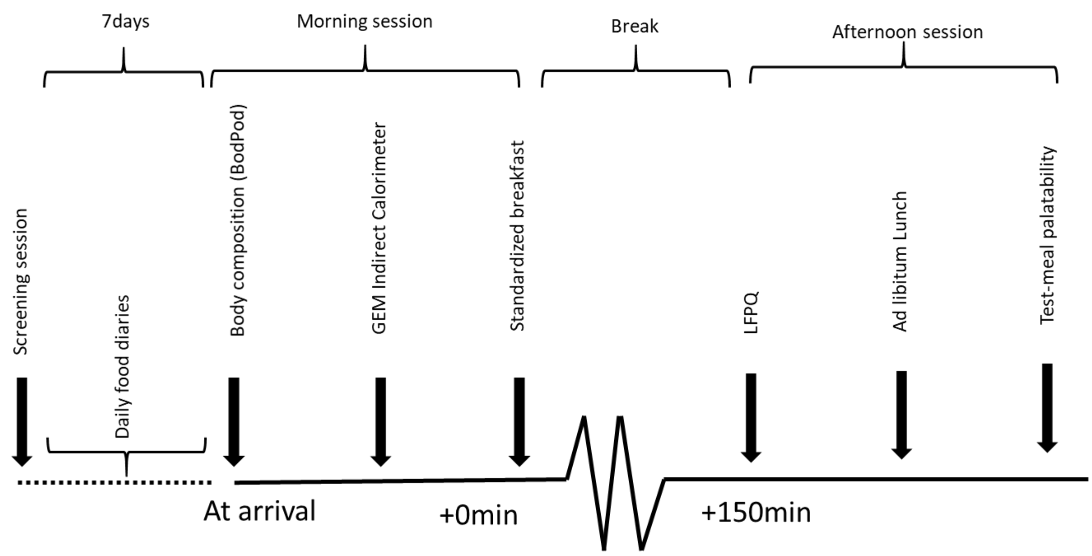

Figure 2.1 Order of the assessment day protocol.

2.3 Participants

Participants from the University of Leeds and surrounding areas volunteered their time for the study. Methods of recruitment included, posters advertising the study around the University of Leeds campus and surrounding areas, an undergraduate participant pool scheme (in which students obtain credits via study participation in order to progress in their studies) and departmental email lists. Full details of each stage of the recruitment process can be seen in Figure 2.2. Participants were classified as either 'overweight' with a BMI of ≥25kg/m^2-34.9 kg/m^2 or 'lean' with a BMI within the range of 18.5-24.9kg/m^2. The DIVA study was sufficiently powered based on previous research to detect differences in *ad libitum* intake between groups. As the use of the LFPQ to compare differences in taste preferences between groups is novel, it was not possible to conduct *a priori* power the DIVA 2.0 study. However, the sample of 86 is – at the time of writing – the largest sample in this field to date.

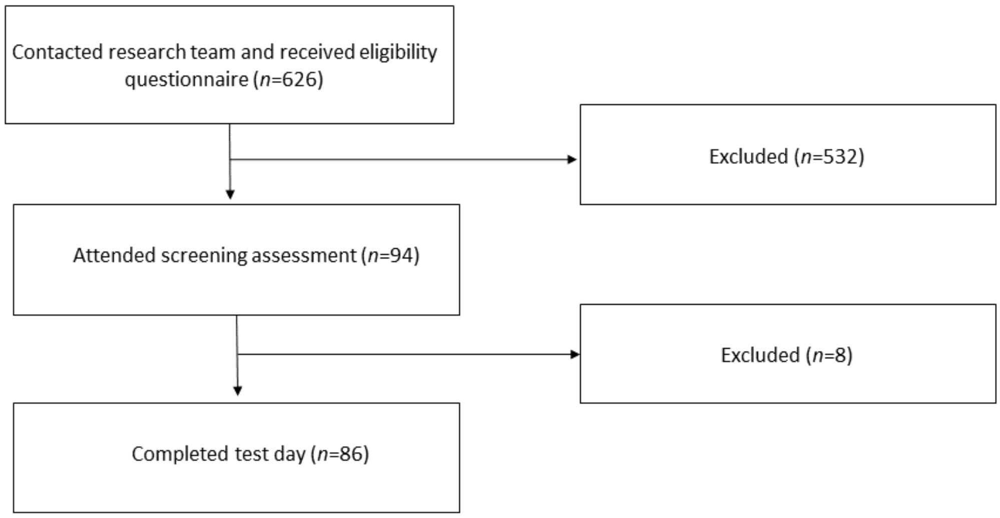

Figure 2.2 Participant recruitment flow-diagram.

Participants were recruited on two separate occasions. Participants characterised as overweight were recruited first (February-August 2018) and provided baseline measurements prior to conducting a randomized control trial investigating weight loss. Participants characterised as lean were recruited following this (March-September 2019) and age-matched to the overweight group based on four age blocks (18-25, 26-34, 35-43 and 44-54 years of age), with the mean age of each block matched. This was done in an attempt to minimise age related effects that exert an influence on food preferences and eating behaviour (Boesveldt et al., 2018)

Participants volunteered their time for the study in return for information regarding their physical activity, metabolism and body composition.

Strict eligibility criteria were defined and adhered to throughout the recruitment process. In order to avoid the confounding effects of habitual exercise or training on appetite (Beaulieu, Hopkins, Blundell, & Finlayson, 2016; Martins, Morgan, & Truby, 2008) recruitment was restricted to individuals who exercised no more than 3 times a week. All participants were non-smokers, not taking any medications that may impact appetite or mood and did not have a history of eating disorders or food intolerances.

All inclusion and exclusion criteria are displayed in Table 2.1 below.

Table 2.1 Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Female participants aged 18 to 55 years at the time of signing informed consent	Significant health problems which in the opinion of the researcher, may jeopardise participant's safety or compliance with the protocol
BMI of 18.5–24.9 kg/m^2 (L)	History of eating disorders including binge eating
BMI of ≥25-34.9 kg/m^2 (OW)	Taking medication or supplements known to alter appetite or weight within the past month and/or during the study
	Pregnant, planning to become pregnant or currently breastfeeding
	History of anaphylaxis to food
	Known food allergies of food intolerances
	Smokers and those who have recently ceased smoking (<6 months)
	BMI < 18.5 kg/m^2
	BMI > 35 kg/m^2
	Volunteers having lost significant amount of weight in the previous 6 months (±4kg)
	Volunteers who exercise >3 days per week or have significantly changed their physical activity patterns in the past 6 months or who intend to change them during the study
	Participants receiving systemic or local treatment likely to interfere with evaluation of the study parameters
	Participants who work in appetite or feed related areas. Participants who do shift work

2.4 Ethical considerations

The present study was granted ethical approval by the University of Leeds, School of Psychology Research Ethics Committee (ref: PSC-238 and PSC-551) and was in compliance with the Declaration of Helsinki. Prior to the commencement of the study, all procedures were explained in full to each participant before informed consent was obtained. In order to avoid the confounding effects of demand characteristics the specific objectives of the study were not disclosed with participants until the end of the assessment day, at which time a full debrief was provided. Participants were informed of their right to withdraw and have any data already collected destroyed up until the beginning of the data analysis process.

2.5 Assessment of eating behaviour

Throughout the study dietary intake was assessed via two methods. Both free living and laboratory eating behaviour measures were obtained in order to provide a detailed understanding of intake in a natural as well as a controlled environment.

2.6 Free living food intake

Allowing participants to remain free to perform their habitual behaviour in a familiar and comfortable environment ensures that food diaries and dietary records as a measurement of habitual energy intake are regarded as highly reliable (Albar, Alwan, Evans, Greenwood, & Cade, 2016). Repeated applications of dietary recall reduces the rate of daily variation and the risk of random measurement error. Consequently a minimum of 7 days assessment was employed within the current protocol.

A possible flaw in the assessment of free living food intake is under-reporting, which is known to be an issue in overweight samples (Gnardellis, Boulou, & Trichopoulou, 1998) as well as female samples (Vance, Woodruff, McCargar, Husted, & Hanning, 2009). However, free living assessment enables assessment of eating behaviours free of the restraints of an artificial environment created in the laboratory.

2.6.1 MyFood24

MyFood24 - an online food diary program specifically developed to serve academic purposes - was selected as the tool to assess habitual dietary intake. The food and drink database has been developed using approximately 50,000 commercially available 'back of pack' nutritional labels mapped onto generic data available from *'The Composition of Foods',* (McCance & Widdowson, 2014). MyFood24 has been established as a valid (Wark et al., 2018) measure and also shown to be comparable to more costly measures such as interviews (Albar et al., 2016). Additionally, it is quick and easy to use for participants and thereby sufficiently navigates participant fatigue and although it does not require formal training to use, all participants were screened and shown how to properly complete a day's diary.

Participants completed 7 days 24 hour food diaries between visit 1 and visit 2. A daily email was sent to each participant at 7pm with a link for that day's food diary, if this was not completed then the following morning a reminder email was sent. Participants selected the meal an entry was to be added to (i.e. breakfast, lunch, dinner or snacks) (Figure 2.3) and searched a database specifically made for MyFood24 use (Carter et al., 2015) (Figure 2.4). Participants selected the portion the best represented their meal, either by selecting a weight or a portion size image (Figure 2.5). This was repeated for every food and drink consumed.

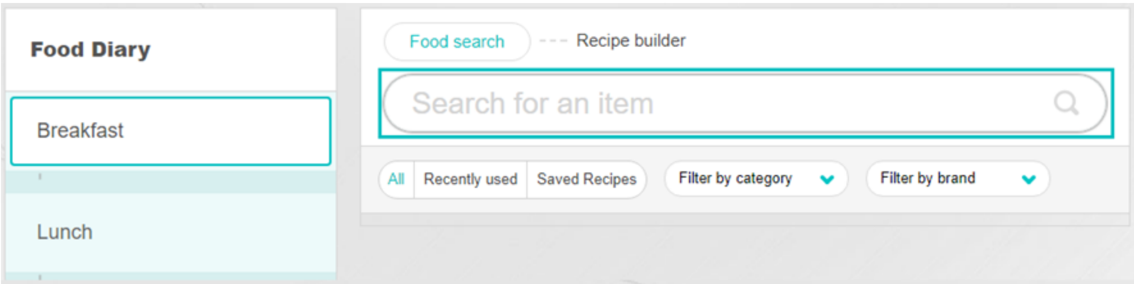

Figure 2.3 MyFood24 meal selection and database search bar.

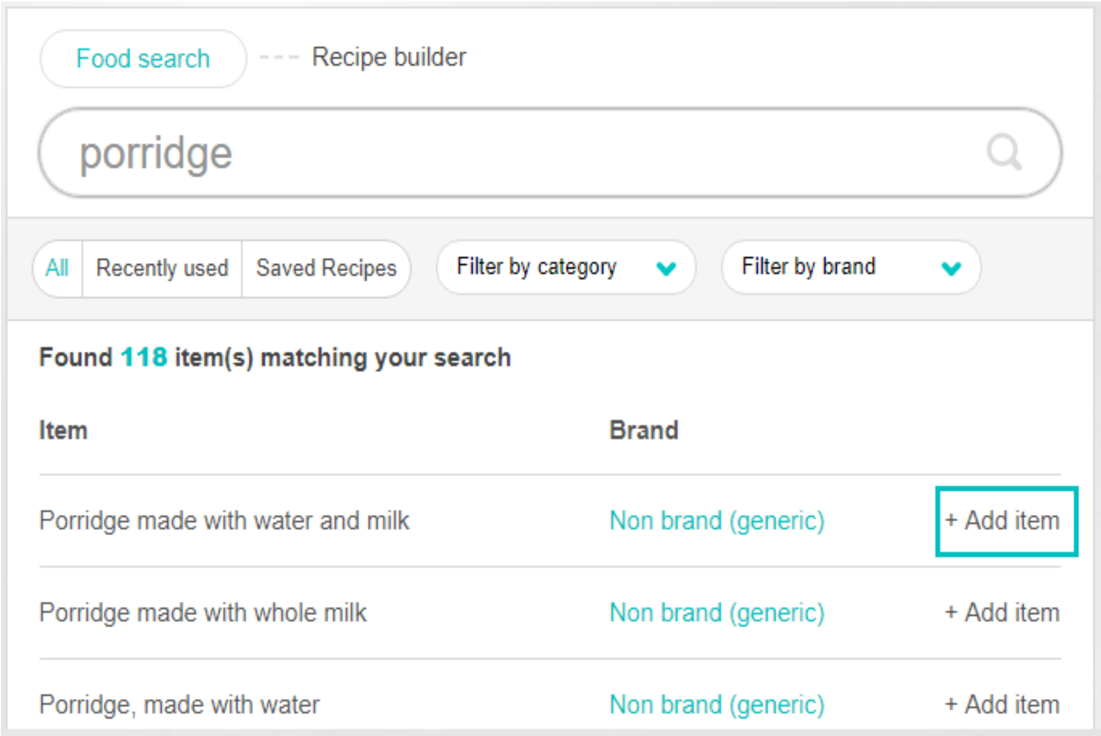

Figure 2.4 MyFood24 example of a food search.

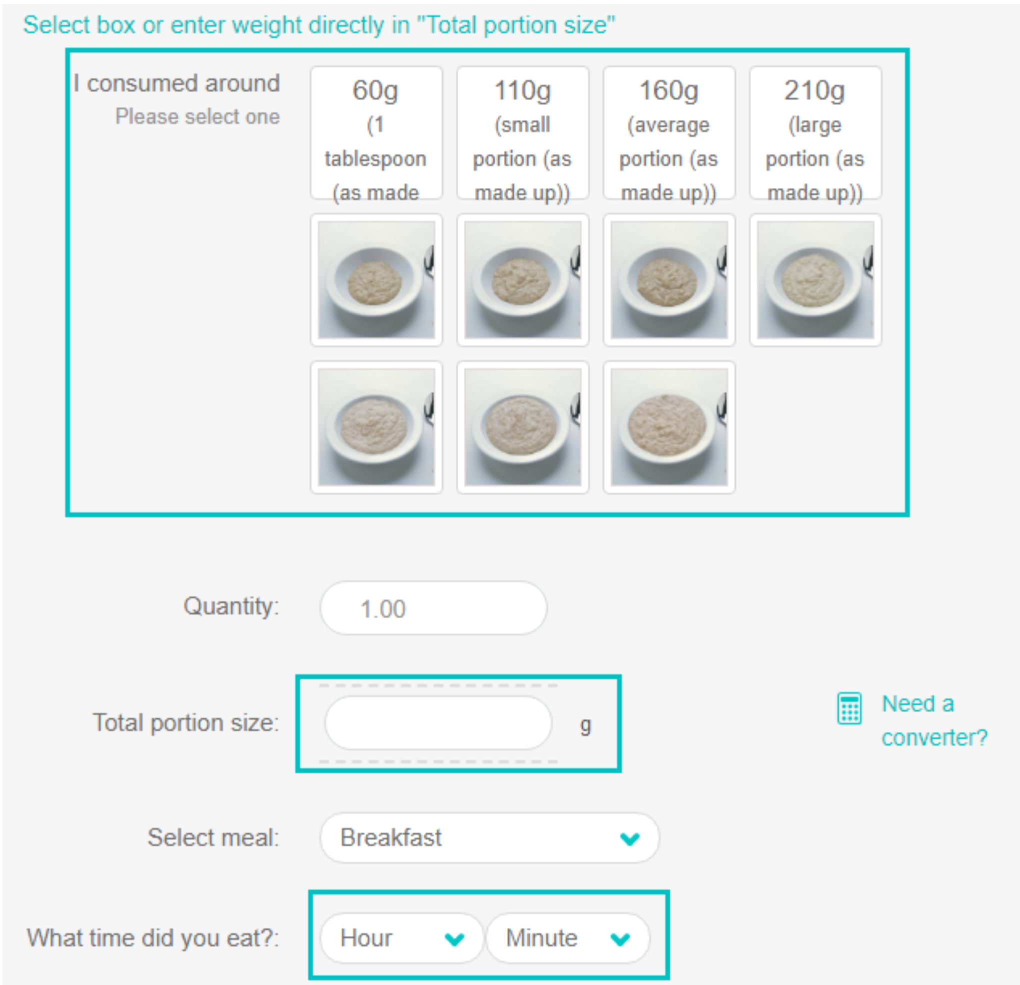

Figure 2.5 MyFood24 portion size selection.

2.7 Laboratory eating behaviour assessment

Assessment of laboratory food intake took place in individual participant cubicles within the HARU. This is a research facility specifically designed to enable the assessment of food intake in a controlled environment. Whilst in the cubicles participants are free from the extraneous variables that are usually present in the surrounding environment, thereby minimising the effects from any confounding variables that may impact their eating behaviour, this includes noise, smells or any social stimuli. Assessment of intake in this manner allows high levels of control which enables a high degree of precision and accuracy of energy and nutrient intake (Arvaniti, Richard, & Tremblay, 2000), however the unfamiliar and unnatural environment can constrain participant's behaviour (Meiselman, 1992).

Laboratory food intake took one of two forms, either fixed intake whereby intake is predetermined by the experimenter (breakfast meal), or *ad libitum* in which participants determine their own meal size (lunch meal), via portions provided in excess of reasonably expected consumption.

2.7.1 Fixed energy test meal

A fixed test meal allows the experimenter to control the energy and nutrient intake by either altering the volume or energy content of a given food or meal. Fixed energy test meals allow standardisation across participants, a benefit of which is that it provides greater experimental control where food intake is an independent variable – as is the case with the present thesis. A disadvantage of fixed tests meals is that individual variation between participants will be present in the amount of energy required, however this can be addressed through standardisation of meals to each participant, such as providing calories at a predetermined percentage RMR.

Participants consumed a standardised breakfast which was calculated based on 25% of their RMR – as previously measured using indirect calorimetry (GEM Nutrition, Cheshire, UK). This meal was calculated to consist of 66% carbohydrates, 14.1%

protein and 19.9% fat. The breakfast consisted of commercially available foods (Neal's Yard Muesli, Neal's Yard Raisins, Neal's Yard Sultanas, Yeo Valley Natural Yoghurt, Sainsbury's Runny Honey, Sainsbury's Semi Skimmed Milk). The quantities of each food item can be seen inTable 2.2, based on a RMR of 1,500kcal. Participants were provided with a drink of either coffee, tea or water. To ensure consistency, participants who did not drink their tea/coffee with milk, had milk added to the same bowl as their breakfast meal.

Coffee was 5g of Nescafe instant coffee grounds, with 500ml of water added to it. Participants were provided with 300g of this mixture. Tea was made by brewing two Yorkshire tea bags in 500ml of boiling water. Similarly, participants were provided with 300g of tea. If participants opted for neither tea nor coffee, they were provided with 300g of chilled water.

Table 2.2 Food and macronutrient composition of the fixed energy breakfast meal based on a resting metabolic rate of 1,500kcal/day.

	Quantity (g)	Carbohydrates (g)	Protein (g)	Fat (g)	Energy (Kcal)
Neal's Yard Muesli Base	46.2	32.3	6.0	2.3	166.1
Neal's Yard Raisins	10.7	7.4	0.2	0.0	28.8
Neal's Yard Sultanas	10.7	7.5	0.3	0.0	29.5
Yeo Valley Natural Yoghurt	131.6	8.6	6.1	5.5	106.1
Sainsbury's Runny Honey	8.6	7.2	0.0	0.0	27.5
Sainsbury's Semi-Skimmed Milk	40.00	1.9	1.4	0.0	16.9
Total	247.9	65.0	14.1	8.3	374.9

Participants were instructed to *"eat and drink everything provided and scrape the bowl when finished",* in order to ensure ingestion of as much as possible of the provided foods.

2.7.2 Ad libitum test meal

Ad libitum test meals require the experimenter to weigh foods before and after consumption to determine the amount of self-determined energy and nutrient intake. Provision of *ad libitum* meals are often more naturalistic than fixed energy meals as participants are capable of determining the amount eaten similar to in everyday life and evidence has shown a high degree of reproducibility (Gregersen et al., 2008). Additionally, due to the large portion sizes this form of assessment will result in the meal cessation occurring due to reasons other than complete consumption of the food provided.

Participants were provided with an ab libitum lunch meal which consisted of water (500g) and two different commercially available foods – Uncle Ben's tomato and herb risotto and Yeo Valley strawberry flavoured yoghurt. The foods were closely matched based on calories which can been seen in Table 2.3. Due to the yoghurt being a lower energy density than the risotto, it was fortified with flavourless maltodextrin (MyProtein). The portions were provided in excess of consumption, although participants were instructed that more food is available should this be necessary. The *ad libitum* test meal can be seen in Figure 2.6. When provided the meal participants were instructed *"to eat and drink as much or as little as you like, until you are comfortably full. If you finish, there is more available".*

Table 2.3 Calorie and macronutrient composition of the *ad libitum* test meal.

	Weight (g)	Kcal	Carbohydrates (%)	Protein (%)	Fat (%)
Uncle Bens' tomato and herb risotto (+ hot water)	900 (+100)	1511.2	70.1	8.9	21.0
Yeo Valley strawberry flavoured yoghurt (+Maltodextrin)	425 (+100)	403.2 (+375)	70.5	8.9	19.7

Figure 2.6 *Ad libitum* test meal.

2.8 Anthropometry and body composition

2.8.1 Height, weight and BMI

Height and weight measures were taken at the pre assessment screening session (visit 1). BMI was calculated by dividing weight in kilograms by height in metres squared (BMI = kg/m^2) and were measured using electronic weighing scales to the nearest 0.1kg and a wall-mounted stadiometer to the nearest 0.1cm (Seca Ltd). Participants wore light clothing although were not required to be in a fasted state.

2.8.2 Air-displacement plethysmography

Air-displacement plethysmography (Bodpod, Concord, USA) is regarded as a gold standard body composition tracking system, capable of providing estimates of both FM and FFM within the body. Testing requires approximately five minutes and has been shown to be a highly reliable measure (Vescovi et al., 2001). Participants are required to wear tight fighting clothing, with unpadded swim suits or tight fitting sportswear recommended, as well as wear a swim cap and remove all jewellery. Measurements require participants to sit inside the test chamber whilst 2 measurements are taken. During this time they are instructed to remain as still as possible and to breathe normally. Available literature comparing air-displacement plethysmography with dual energy x-ray absorptiometry does not demonstrate any difference %BF between measurement techniques (Ballard, Fafara, & Vukovich, 2004) and has confirmed it as a valid assessment of body composition for both lean (Fields, Goran, & McCrory, 2002) and obese individuals (Ginde et al., 2005) and in women (Maddalozzo, Cardinal & Snow, 2002).

The Bodpod uses body density to determine body composition:

$$\text{Body density} = \text{body weight} / \text{body volume}$$

Total volume is measured using air and follows Boyle’s law which states, “For a fixed mass of ideal gas at fixed temperature, the product of pressure and volume is a constant”. This requires participants to sit in one of two chambers which creates a change in air pressure and volume. A diaphragm then measures these changes and Boyle’s Law is used to measure whole body volume. Once overall body density is known, equations related to body density can be applied to calculate the proportions of FM and FFM. FFM is denser than adipose tissue and so from a higher body density it a higher percentage of FFM is inferred. The Siri equation was used to translate whole body density into body fat percentage:

$$\text{Percent fat} = (495/\text{density}) - 450$$

The percentage of fat-free mass was then calculated using the percentage of fat mass:

$$\text{Percent fat-free mass} = 100 - \text{percent fat}$$

2.8.3 GEM indirect calorimeter

RMR was measured following guidelines outlined by the American Dietetic Association (Compher, Frankenfield, Keim, & Roth-Yousey, 2006) via an indirect calorimeter fitted with a ventilated food. The GEM indirect calorimeter provides a measures of RMR, respiratory quotient and energy expenditure.

Participants were required to remain awake but motionless in a supine position for approximately 40 minutes (~10 minutes calibration and 30 minutes data collection). The average of 30 minutes collection was used to determine RMR. VO_2 and VCO_2 were calculated from O_2 and CO_2 concentrations in inspired and expired air diluted in a constant airflow of ~40 L/min, individually calibrated for each participant and averaged over 30 second intervals. Standard stoichiometric equations used by the software calculated respiratory exchange rate (RER).

2.9 Sweet taste preference assessment

The Leeds Food Preference Questionnaire (LFPQ) (Finlayson, King, & Blundell, 2008) is a computer-based procedure designed to assess two distinct psychological components of food reward – liking and wanting. The test utilises sixteen images of common food stimuli varying in fat content (high [HF] or low [LF]) and taste (sweet [SW] or savoury [SA]), with the combination of fat content and taste producing four categories (HFSW, LFSW, HFSA and LFSA). Two different question formats allow measurement of explicit liking, explicit wanting and implicit wanting, with the two separate procedures preventing cross contamination between the two concepts. Table

2.4 shows the standard list of food images used in the LFPQ for the present thesis, in instances of low acceptance of foods (established and confirmed during screening at visit 1) there were a number of additional images for each category that could be substituted.

Table 2.4 Photographic food stimuli used in the LFPQ.

Savoury		Sweet	
High fat	Low fat	High fat	Low fat
Garlic bread	Cucumber	Jam Biscuits	Apple
Crisps	Bread roll	Doughnuts	Strawberries
Chips	Pilau rice	Chocolate fingers	Skittles
Peanuts	Potatoes	Chocolate	Marshmallows

2.9.1

2.9.2 Explicit liking and wanting assessment

In order to measure explicit liking food images are presented in a randomised order individually via a VAS. Participants are required to rate *"How pleasant would it be to taste some of this food now?"* on 100mm scales with weighted answers at either end *"Not at all"* and *"Extremely"*. EW is assessed in a similar manner although participants answer *"How much do you want some of this food now?"*. A representation of this assessment can be seen in Figure 2.7.

Mean sweet scores can be subtracted from the mean for savoury scores to provide a 'sweet bias score, for sweet versus savoury foods for each outcome. Similarly, mean low fat scores can be subtracted from the mean for high fat scores to provide a 'fat bias score, for high fat versus low fat foods for each outcome. Scores for sweet bias score usually range 0 to 48 and for fat bias score range from -48 to 48.

EL and EW category scores (HFSA, LFSA, HFSW, LFSW) are obtained by averaging the ratings for each category for each participant. A higher score indicates a higher EL or EW respectively.

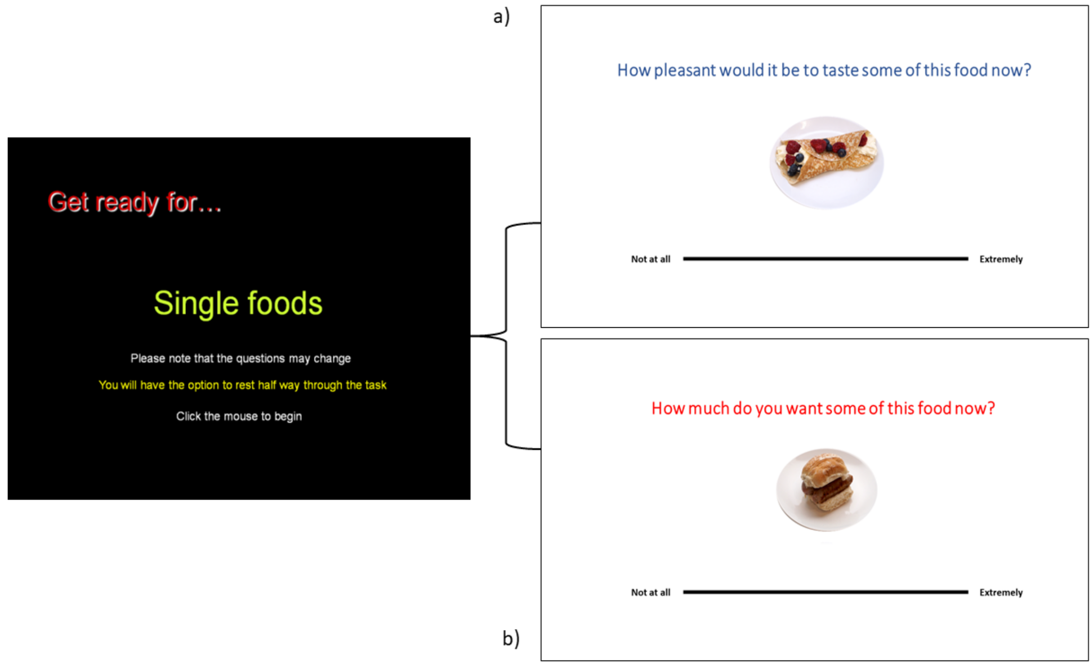

Figure 2.7 Representation of the a) EL and b) EW trials in the LFPQ.

2.9.3 Implicit wanting assessment

IW is assessed through the use of a forced choice procedure in which food images are paired so that every image used is compared to every other image over ninety-six trials. Participants answer the question *"Which food do you most want to eat now?"*. A representation of a trial can be seen in

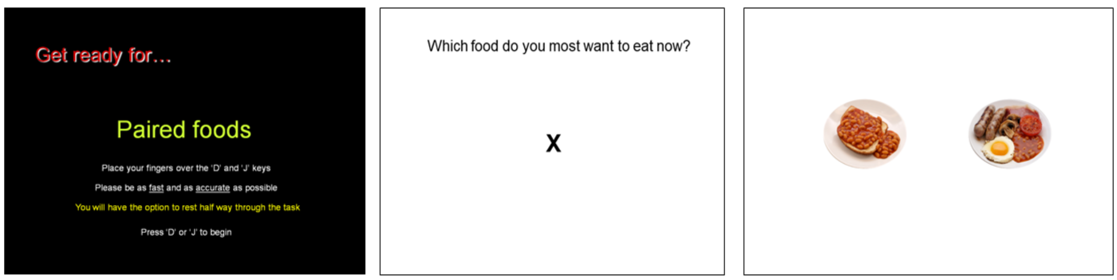

Figure 2.9. Participants are instructed by the experimenter to respond as quickly and as accurately as possible and focus only on the type of food shown. Scores are relative to the other food choices with a frequency weighed algorithm used that is influenced by both the frequency of food choices and reaction times of answers – as shown in Figure 2.8 (Dalton & Finlayson, 2014). IW sweet/fat bias scores usually

range from -100 to 100 as there is no fixed min/max value due to the inclusion of reaction time.

$$\text{'Frequency} - \text{weighted algorithm'}: I_A = \sum_{i=1}^{N_{win}} \frac{\bar{t}}{t_i} - \sum_{j=1}^{N_{lose}} \frac{\bar{t}}{t_j}$$

Figure 2.8 Frequency weighted algorithm used to score LFPQ IW.

Note. I_A= Implicit wanting for category. A; N_{win}= number of times category A was selected. N_{lose}= number of times category A was not selected. $\dot{t}$= mean of all reaction times. $\dot{t}_{win}$ = mean reaction time for category A selections; $\dot{t}_{lose}$ = mean reaction time for non category A selections.

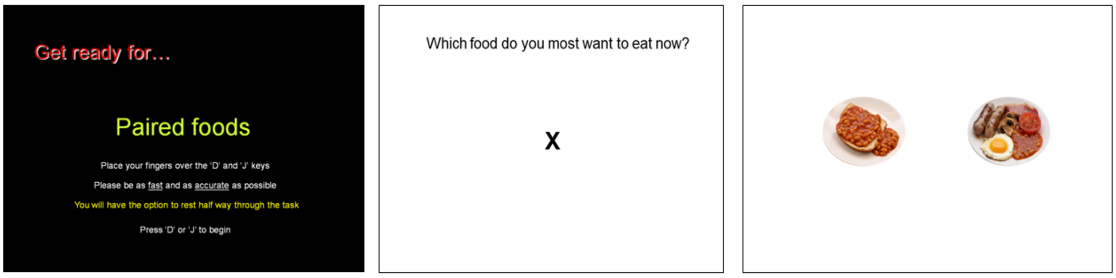

Figure 2.9 Representation of the implicit wanting trials in the LFPQ.

2.9.4 LFPQ procedure

Initial acceptability of the food images was confirmed at the initial screening session in order to improve the internal validity with an alternative food from the same category believed to yield better than a fixed food that is avoided.

Questions were provided in one of two formats, either a single image of food with answers provided on a VAS or paired images of food. The format of questions was delivered randomised in order to prevent order effects, with some participants completing the single image trials first and the paired image trials second and vice versa.

Participants sat in an isolated room at a desktop terminal. Before the trial began participants were instructed that the questionnaire would measure their food preferences and involved images of real foods. Participants were instructed to answer single images of foods by clicking the mouse at the point on the line that best represented how they felt. Once the mouse had been clicked the next question was automatically loaded on screen. Images of two paired foods required participants to place their left hand on the ‘D’ key and right hand on the ‘J’ key on the keyboard which corresponded to the images on screen. Participants were instructed to choose which food item they wanted most at that moment in time and focus only on the type of food shown rather than the quantity shown.

Before beginning the experimental trials participants completed a block of practise trials. The on-screen instructions provided to participants at the beginning of the questionnaire can be seen in Figure 2.10.

Figure 2.10 Instructions provided to participants prior LFPQ completion.

2.10 Subjective palatability assessment

VAS scores are used consistently within appetite research to continuously monitor a range of subjective sensations (Andriessen et al., 2018; Gilbert, Drapeau, Astrup, & Tremblay, 2009; Iatridi, Hayes, & Yeomans, 2019b) and have been reliably established for use within this field (Rahemtulla et al., 2005).

Following completion of the *ad libitum* lunch meal participants answered palatability ratings on a 100-mm VAS. Scales were anchored with extreme appetite sensations at both ends, participants were instructed to score on the line how they felt in response to the questions at that moment in time on a scale from *'Not at all'* (score of 0) to *'Extremely'* (score of 100). Participants provided subjective ratings regarding how sweet/savoury, pleasant, and how much they liked the *ad libitum* test food items.

Subjective palatability questions were completed using pen and paper, with experimenters measuring responses by hand. Questions provided to participants can be seen in Appendix 2.

2.11 Statistical Analysis

Data were analysed using Statistical Package for the Social Sciences v.25 (SPSS; IBM Corporation, Somers, New York). All collected data were exported into MS Excel which was used to calculate the variables for export to SPSS. LFPQ data was collected using E-Prime v.2.0 software and exported into MS Excel.

All data were visually explored with histograms and stem and leaf plots in SPSS to establish normality of distributions and any potential outliers. Data was normally distributed and no outliers were identified and all data available was used within the analysis. In certain instances data was missing or incomplete and so for each statistical test the sample size is provided.

All statistical procedures are described in greater detail in the results section of each experimental chapter.

Chapter 3 What is the relationship between preferences for sweet taste or sweet/fat combinations and eating behaviours?

3.1 Aims

The preference for sweet taste (i.e. a preference towards sweet only or a preference towards sweet and fat combinations) should be evident in eating behaviours, reflected within *ad libitum* test meal and habitual intake. This is suggested by early historical data collected via FFQs and frequency checklists. The aim of the present chapter is to examine whether specific preferences for sweet taste and sweet/fat combinations are reflected in eating behaviour variables in laboratory and free-living environments.

3.2 Introduction

Eating behaviour is a broad term encompassing food choices and feeding practices (LaCaille, 2013). These behaviours are determined by numerous factors, including individual differences, the external environment and economic or demographic variables (Drewnowski, 1997; Roos, Lahelma, Virtanen, Prättälä, & Pietinen, 1998; Zagorsky & Smith, 2017). Food preferences, through the use of focus group discussions, have been identified as an important factor in determining food choices (Deliens, Clarys, De Bourdeaudhuij, & Deforche, 2014) and taste has been stated as the main influence on food selection (Food Marketing Institute. Research Dept, & Opinion Research Corporation (US), 1996). Moreover, palatability is believed to have a major impact on food selection and intake, with intake increasing or decreasing in proportion to palatability (Bobroff & Kissileff, 1986; de Castro, 2000) and with palatability becoming more important with increasing portion size (Brunstrom et al., 2016).

Food preference checklists are often used to predict food consumption in real life (Meiselman, Waterman, & Symington, 1974) as taste preferences are believed to be directly linked to food consumption patterns. Similarly, FFQs when used to assess frequency of intake of specific foods, highlight the existence of a link between self-reported food preferences and frequency of consumption of these same foods (Kaminski, Henderson, & Drewnowski, 2000). Despite this evidence stemming from early data within the area, it demonstrates a consistent association between eating behaviours and taste preferences across different assessment techniques

Taste preference studies have demonstrated a preference towards fat-rich stimuli in participants with obesity (Mela & Sacchetti, 1991); these participants exhibit a preference for a higher ratio of fat to sweet taste, whereas lean counterparts exhibit a preference for a higher sweet to fat ratio (Drewnowski, Brunzell, Sande, Iverius, & Greenwood, 1985). This is a finding consistent with data obtained via intake studies and self-reporting checklists, which have both shown positive associations between obesity and dietary fat intake but not sugar intake (Gibney, Sigman-Grant, Stanton & Keast, 1995; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992). More recently, it has been demonstrated that liking for sweet and fat may be linked to overconsumption of corresponding foods, particularly in women (Deglaire et al., 2015). Given that hedonic responses are dissociable from motivation (i.e. liking vs. wanting) (Berridge, 1996) which influences food choices and intake (de Graaf & Boesveldt, 2017; Finlayson & Dalton, 2012) it may be reasoned that liking and wanting towards sweet and fat tastes will be reflected in intake of foods high in sugar or fat.

An elevated consumption of fats and energy intake is associated with a higher liking for fat foods (Méjean et al., 2014). This evidence supports conclusions that taste preference is reflected in food intake and would suggest that a HFSW or LFSW preference would result in higher intake of such foods in participants with varying body compositions. A study investigating liking noted that relative to lean counterparts, obese participants had a higher liking for energy-dense foods and sweet foods

(Proserpio, Laureati, Bertoli, Battezzati, & Pagliarini, 2015). In this study all food groups were liked significantly more by the obese with the exception of ‘fruits’, ‘dairy products’ and ‘vegetables’ – which suggests it may not be the sweet taste preference *per se* that is detrimental, rather the combination of this with other nutritional aspects.

In addition, evidence supports the notion that a diet consisting of high-fat foods may be characteristic of obesity (Bray et al., 2004; Ricketts, 1997; Woods, Seeley, Rushing, D’Alessio, & Tso, 2003) and it is argued that sugar intake serves as a vehicle for increased fat intake (Drewnowski et al., 1997; Emmett & Heaton, 1995), with the inclusion of both sugar and fat increasing global palatability and consumption (Macdiarmid, Vail, Cade, & Blundell, 1998). Evidence obtained via a prospective study in a large French population (*n* = 24,776) found that those individuals with a higher liking for both sweet and fat had a higher total energy intake. Furthermore, it was established that a higher liking for HFSW foods at baseline was also associated with a greater risk of developing obesity at 5 year follow up – a finding only significant in women (Lampuré et al., 2016). This evidence demonstrates the manner in which taste preferences can influence eating behaviours negatively and contribute to excess intake and weight gain. For this reason it is hypothesised that a higher HFSW preference will be positively associated with a larger amount of energy obtained from sugar and fat within the habitual diet.

To date current work examining taste preferences has primarily focused on ‘liking’ as an indication of taste preferences. However, both concepts contribute to food reward and by extension, the expression of taste preferences (see Figure 1.3). The present study will expand on the already available evidence by examining the associations between both liking and wanting with eating behaviour variables.

The available evidence suggests the existence of a relationship between taste preference and food choice and EI. To our knowledge the use of the LFPQ to examine associations between different sweet taste preferences (sweet and sweet/fat combinations) and eating behaviour variables measured in both the laboratory and a free-living situation is novel. This will provide an extra theoretical dimension to the existing literature through investigation of taste preferences defined as both liking and wanting as well as potential associations with eating behaviours.

Hypotheses;

1. Higher sweet taste preference will be associated with higher intake of a sweet food item in an *ad libitum* test meal.
2. Higher sweet taste preference will be associated with higher palatability ratings to a sweet food in a test meal.
3. Higher HFSW taste preference will be associated with a higher intake of both sugar and fat in the habitual diet.
4. Higher sweet taste preference will be associated with a higher intake of sugar in the habitual diet.

3.3 Methods

Prior to the assessment day participants were required to complete a 24-hour food diary (MyFood24), for 7 days. This provided information regarding their habitual food intake which was divided into macronutrients (absolute and percentage values) and total energy intake. Food preferences were measured (LFPQ) on assessment days, approximately 2 hours 45 minutes after consumption of a fixed energy breakfast meal (details can be seen in section 2.6.1). During their assessment day in the laboratory an *ad libitum* test meal was provided, comprised of both sweet (yoghurt) and savoury (risotto) foods. Risotto was selected for inclusion to provide a non-sweet food alternative to the yoghurt, enabling a comparison between sweet and non-sweet (in this instance, savoury) food intake in a single test meal. The foods were selected due to their homogenous portions, familiarity to participants and their successful inclusion in *ad libitum* test meals previously within the HARU. Subjective palatability and sweet/savoury intensity ratings to the *ad libitum* test meal food items were also collected immediately after consumption. The measures of palatability can be seen in Appendix 2 with intensity measures addressed via question 1, pleasantness measures addressed via question 5 and liking measures assessed via question 8 on the sweet and savoury versions of the palatability questionnaires. A timeline of measures can be seen in Figure 3.1.

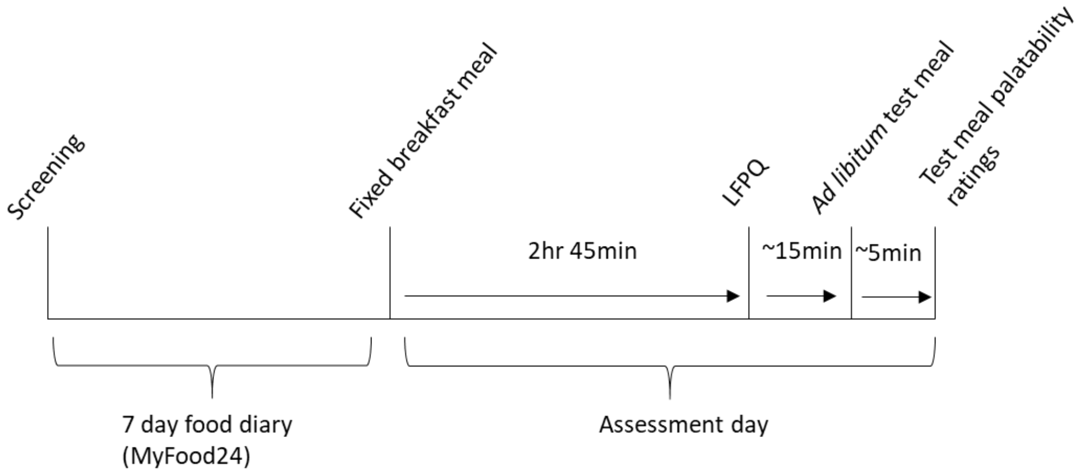

Figure 3.1 Timeline of measures.

3.4 Statistical analyses

Bivariate Pearson's correlations were used to examine associations between taste preferences (EL, EW, IW sweet bias, fat bias and HFSW, LFSW, HFSA, LFSA scores) and *ad libitum* intake (sweet, savoury and total intake in calories and yoghurt intake as a percentage of total intake (yoghurt intake (kcal) / total intake (kcal) = yoghurt (%))), palatability ratings (sweet pleasantness, liking for sweet taste, savoury pleasantness, liking for savoury taste) and sweet/savoury intensity ratings to the test meal food items as well as habitual food intake. All results are displayed as means, minimum and maximum value and standard deviations.

It was not considered necessary to examine *ad libitum* intake as both absolute (g) and energy-density (kcal) values within the *ad libitum* test meal as the two food items were matched for energy density (see section 2.6.2). For this reason intake was expressed in energy-density (kcal) rather than absolute (g) values. Moreover, yoghurt intake was divided by total energy intake to provide yoghurt (%) – representative of yoghurt intake as a percentage of total energy intake. This thereby provides a more accurate indication of sweet food intake in a single meal as it is relative to the total intake of the meal and therefore not confounded by total intake as is the case with an absolute intake.

3.5 Results

3.5.1 Taste preference and *ad libitum* test meal intake

Table 3.1 contains the descriptive statistics for the LFPQ across the whole sample. This is broken down EL, EW and IW for each food category (HFSW, LFSW, HFSA and LFSA) as well as sweet bias and fat bias scores. In addition, Table 3.2 contains the descriptive statistics for the *ad libitum* test meal intake.

Table 3.1 EL, EW and IW descriptive statistics (n = 84).

	Mean	Minimum	Maximum	SD
EL HFSW	53.70	2.50	95.75	23.89
EL LFSW	51.87	4.25	98.25	19.53
EL HFSA	62.57	6.00	97.00	16.98
EL LFSA	53.28	10.50	95.50	18.51
EL Sweet bias	-5.14	-77.00	44.88	20.98
EL Fat bias	5.56	-31.13	58.50	12.75
EW HFSW	46.13	1.25	94.25	24.63
EW LFSW	45.38	6.00	97.75	20.25
EW HFSA	59.00	4.75	95.75	17.33
EW LFSA	49.68	1.50	93.50	18.84
EW Sweet bias	-8.59	-70.50	46.00	21.82
EW Fat bias	5.04	-31.50	47.63	13.08
IW HFSW	-8.53	-60.03	65.82	28.83
IW LFSW	-14.75	-70.06	52.44	26.28
IW HFSA	20.77	-28.17	79.35	24.40
IW LFSA	2.51	-55.97	54.88	28.32
IW Sweet bias	-23.28	-87.86	59.17	38.42
IW Fat bias	12.24	-63.77	70.46	26.92

Abbreviations. EL = explicit liking. EW = explicit wanting. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. SD = standard deviations.

Table 3.2 Descriptive statistics of the *ad libitum* test meal intake (n=86).

	Mean	Minimum	Maximum	SD
Yoghurt (kcal)	251.55	0.00	877.37	167.96
Risotto (kcal)	602.78	103.81	992.88	184.55
Total (kcal)	854.34	250.26	1415.63	238.72
Yoghurt (%)	28.37	0.00	73.35	15.52

Abbreviations. SD = standard deviations.

Bivariate Pearson's correlations showed a significant positive association between yoghurt intake (kcal) and total intake (kcal) ($r(86) = .638$, $p = < .001$) and risotto intake (kcal) and total intake (kcal) ($r(86) = .713$, $p < .001$) with no association between yoghurt intake (kcal) and risotto intake (kcal) ($r(86) = -.085$, $p = .435$). Yoghurt intake (%) was positively correlated with yoghurt intake (kcal) ($r(86) = .871$, $p < .001$), risotto intake (kcal) ($r(86) = -.469$, $p < .001$) and total intake (kcal) ($r(86) = .250$, $p = .020$).

3.5.1.1 Explicit liking (EL)

Table 3.3 displays the results of Bivariate Pearson's analysis for EL taste preferences and *ad libitum* test meal intake. Analysis identified a positive association between sweet bias and yoghurt intake (kcal). Positive associations were present between LFSA score and risotto intake (kcal) and total intake (kcal), yoghurt intake (%) and sweet bias and LFSW, with no other significant associations.

Figure 3.2 displays the associations between EL sweet bias and fat bias scores and intake of the *ad libitum* test meal items and Figure 3.2 displays the association between EL sweet bias and yoghurt intake (%).

Table 3.3 Correlations for EL taste preference and *ad libitum* test meal intake (n = 84).

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Yoghurt (kcal)	**.244 (.026)**	-.022 (.843)	.155 (.162)	.232 (.035)	-.054 (.630)	-.062 (.581)
Risotto (kcal)	-.180 (.104)	-.070 (.529)	.073 (.511)	-.031 (.780)	.134 (.226)	**.347 (.001)**
Total (kcal)	.033 (.770)	-.069 (.536)	.164 (.139)	.137 (.216)	.065 (.559)	**.222 (.044)**
Yoghurt (%)	**.302 (.005)**	.022 (.843)	.169 (.126)	**.262 (.017)**	-.058 (.604)	-.140 (.208)

Note: Data are Pearson's *r* (p-value).
Abbreviations. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. P<0.05 shown with bold emphasis.

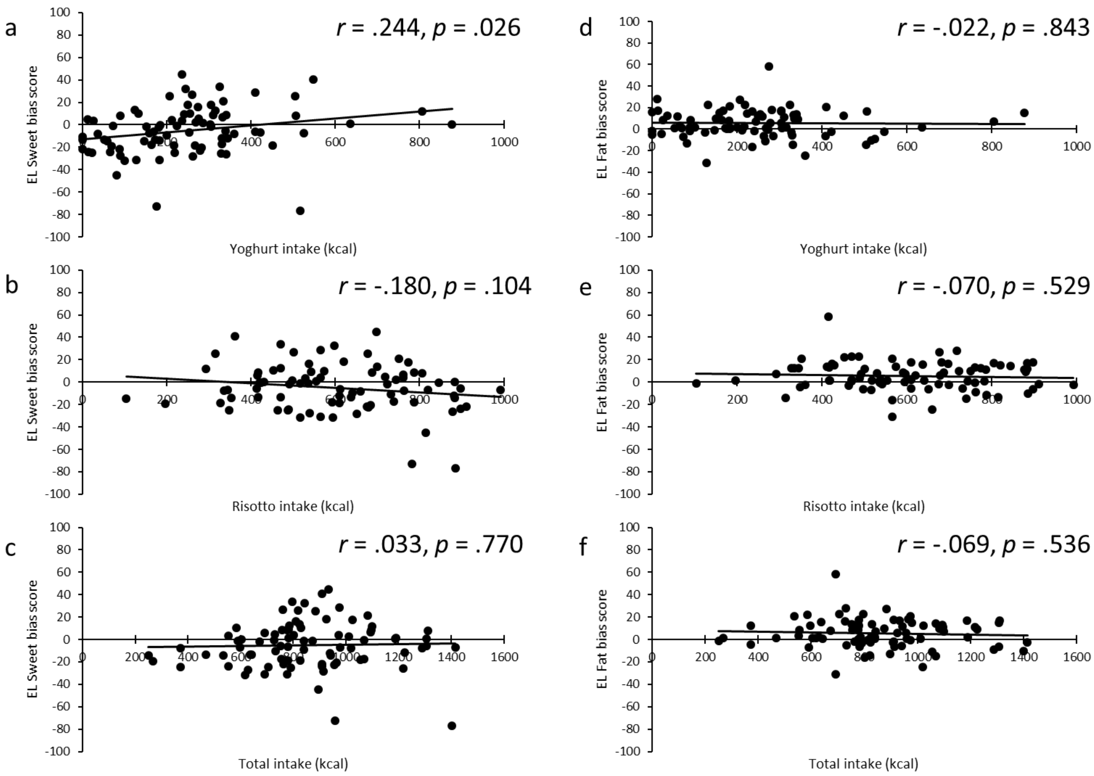

Figure 3.2 The relationship between explicit liking sweet bias and yoghurt intake (a), risotto intake (b) and total intake (c) and fat bias scores and yoghurt intake (d), risotto intake (e) and total intake (f).
Abbreviations. EL = explicit liking.

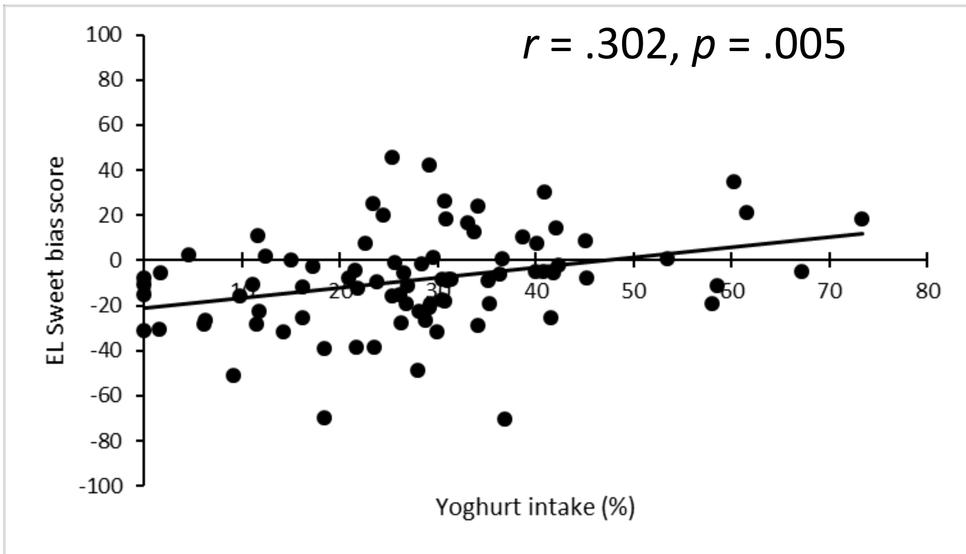

Figure 3.3 The association between explicit liking sweet bias score and percentage of yoghurt intake.
Abbreviations. EL = explicit liking.

3.5.1.2 Explicit wanting (EW)

Table 3.4 displays the Bivariate Pearson's analysis results for EW taste preferences and *ad libitum* test meal intake. Analyses identified a positive association between EW sweet bias and yoghurt intake (kcal and %) and a negative association with risotto intake (kcal). LFSA score was positively associated with risotto intake (kcal) and negatively associated with yoghurt intake (%). Both HFSW and LFSW were positively associated with yoghurt intake (%), with no other significant associations. Figure 3.4 shows the relationships between EW sweet and fat bias scores and intake of the *ad libitum* test meal items and Figure 3.5 displays the association between EW sweet bias and yoghurt intake (%).

Table 3.4 Correlations EW taste preference and *ad libitum* test meal intake (n = 84).

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Yoghurt (kcal)	**.255 (.020)**	.076 (.495)	.179 (.105)	.209 (.058)	-.021 (.853)	-.114 (.304)
Risotto (kcal)	**-.247 (.024)**	-.197 (.075)	-.036 (.747)	-.062 (.578)	.091 (.412)	**.375 (.001)**
Total (kcal)	-.011 (.921)	-.097 (.382)	.097 (.382)	.098 (.377)	.055 (.620)	.207 (.060)
Yoghurt (%)	**.332 (.002)**	.181 (.102)	**.219 (.047)**	**.225 (.041)**	-.020 (.858)	**-.224 (.042)**

Note: Data are Pearson's r (p-value).
Abbreviations. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

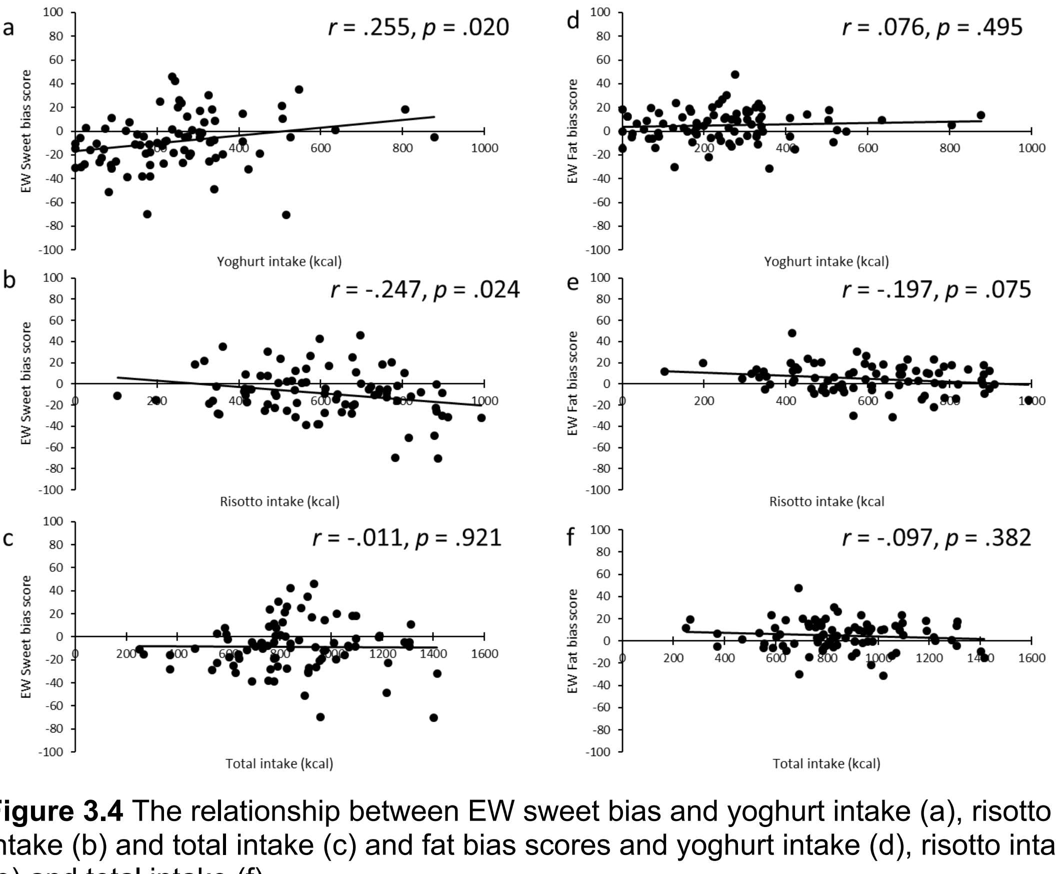

Figure 3.4 The relationship between EW sweet bias and yoghurt intake (a), risotto intake (b) and total intake (c) and fat bias scores and yoghurt intake (d), risotto intake (e) and total intake (f).
Abbreviations. EW = explicit wanting.

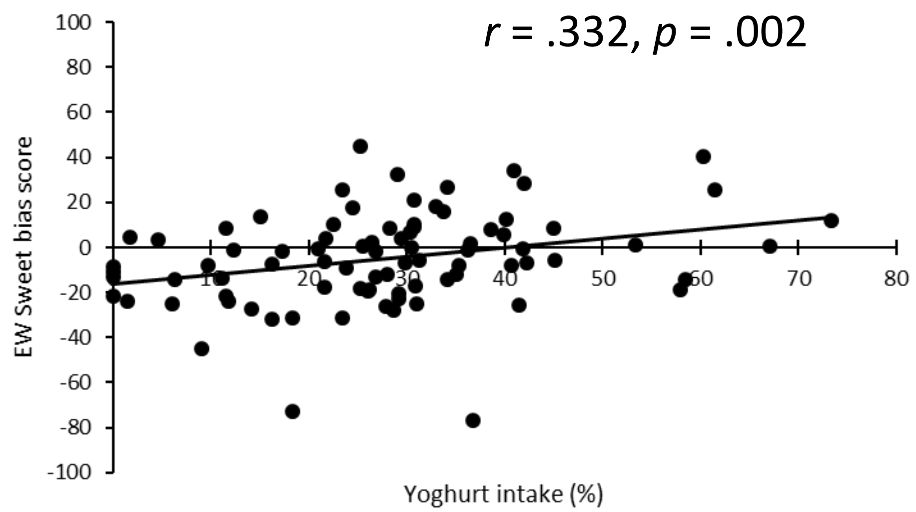

Figure 3.5 The association between EW sweet bias score and percentage of yoghurt intake.
Abbreviations. EW = explicit wanting.

3.5.1.3 Implicit wanting (IW)

Table 3.5 displays the results of Bivariate Pearson's analysis for IW taste preference and *ad libitum* test meal intake. Analysis identified a positive association between sweet bias and yoghurt intake (kcal) and yoghurt intake (%) and a negative association with risotto intake (kcal). LFSA score was negatively associated with yoghurt intake (kcal) and yoghurt intake (%) and positively associated with risotto intake (kcal). Both HFSW and LFSW were positively associated with yoghurt intake (%), with no other significant associations Figure 3.6 displays the relationships between IW sweet and fat bias scores and *ad libitum* test meal intake and Figure 3.7 displays the association between EL sweet bias and yoghurt intake (%).

Table 3.5 Correlations for IW taste preference and *ad libitum* test meal intake (*n* = 84).

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Yoghurt (kcal)	**.286 (.009)**	.026 (.814)	.172 (.120)	.231* (.036)	-.174 (.115)	**-.238 (.030)**
Risotto (kcal)	**-.258 (.018)**	-.152 (.171)	-.157 (.155)	-.205 (.063)	.019 (.864)	**.334 (.002)**
Total (kcal)	.002 (.986)	-.097 (.381)	-.001 (.995)	.004 (.975)	-.107 (.338)	.089 (.423)
Yoghurt (%)	**.372 (.001)**	.125 (.261)	**.263 (.016)**	**.256 (.020)**	-.174 (.115)	**-.355 (.001)**

Note: Data are Pearson's *r* (p-value). Abbreviations. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

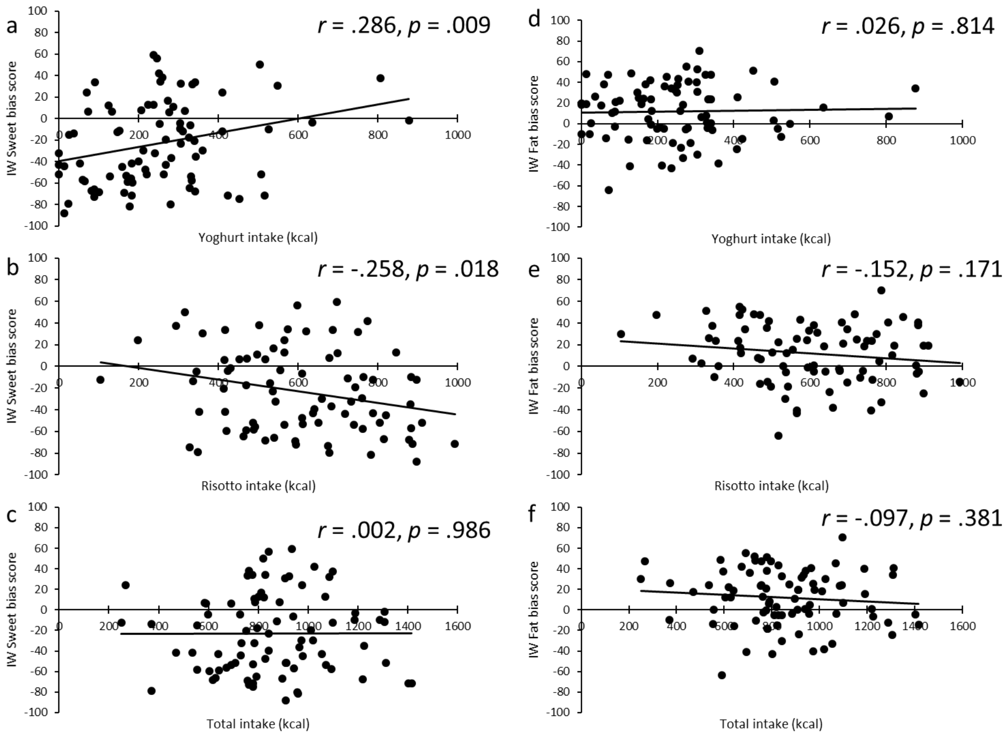

Figure 3.6 The relationship between implicit wanting sweet bias and yoghurt intake (a), risotto intake (b) and total intake (c) and fat bias scores and yoghurt intake (d), risotto intake (e) and total intake (f).
Abbreviations. IW = implicit wanting.

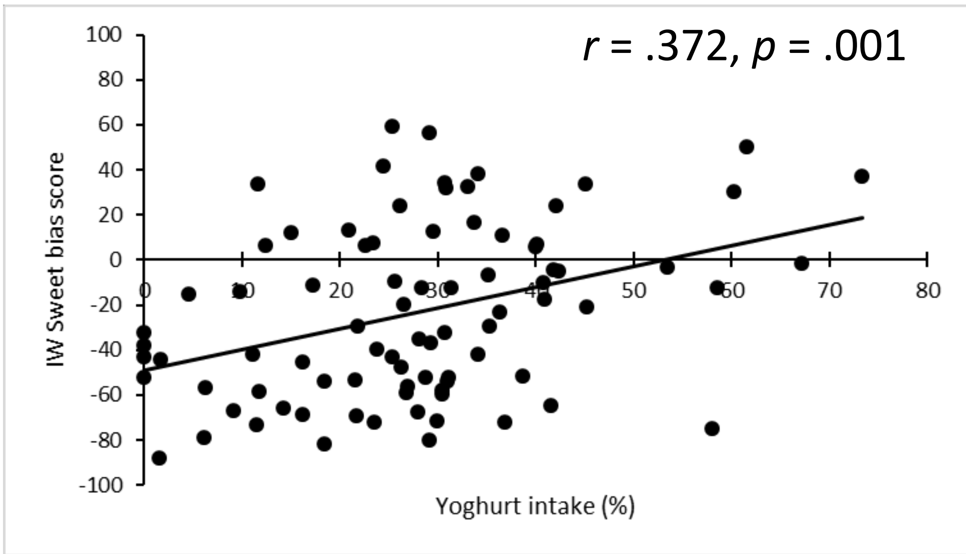

Figure 3.7 The association between implicit wanting sweet bias score and percentage of yoghurt intake.
Abbreviations. IW = implicit wanting.

3.5.2 Taste preference and test meal palatability ratings

Table 3.6 contains the descriptive statistics for the test meal palatability ratings for the entire sample, with sweet palatability ratings in response to a sweet food (yoghurt) and savoury palatability ratings in response to a savoury food (risotto).

Table 3.6 Descriptive statistics for the test meal palatability ratings regarding intensity, pleasantness and liking of both a sweet and savoury food items (*n* = 86).

	Mean	Minimum	Maximum	SD
Sweet intensity (mm)	72.57	0	100	21.13
Sweet pleasantness (mm)	71.58	0	100	25.42
Liking for sweet taste (mm)	68.91	0	100	26.17
Savoury intensity (mm)	70.21	5	100	19.11
Savoury pleasantness (mm)	70.86	3	100	18.73
Liking for savoury taste (mm)	68.20	4	100	21.74

Note: Data are Pearson's *r* (p-value).
Abbreviations. SD = standard deviation.

3.5.2.1 Explicit liking (EL)

Table 3.7 displays the results of Bivariate Pearson's analysis between EL taste preference and test meal palatability ratings. Analysis identified positive associations between LFSW score and 'sweet pleasantness', and LFSA score and 'savoury intensity' and 'liking for savoury taste', as displayed in Figure 3.8. No other significant associations were present.

Table 3.7 Correlations between EL taste preferences and test meal palatability ratings.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sweet intensity (mm)	-.159 (.147)	-.141 (.200)	-.131 (.233)	-.111 (.316)	-.036 (.742)	.108 (.326)
Sweet pleasantness (mm)	.165 (133)	-.052 (.637)	.175 (.111)	**.226 (.039)**	.016 (.885)	.074 (.502)
Liking for sweet taste (mm)	.109 (.323)	-.056 (.612)	.152 (.167)	.145 (.187)	-.010 (.929)	.111 (.314)
Savoury intensity (mm)	-.011 (.918)	-.063 (.571)	.141 (.200)	.190 (084)	.185 (.091)	**.238 (.029)**
Savoury pleasantness (mm)	-.094 (.395)	.009 (.933)	.070 (.527)	-.031 (.782)	.088 (.426)	.190 (.083)
Liking for savoury taste (mm)	-.207 (.059)	-.098 (.377)	-.025 (.821)	-.118 (.284)	.047 (.674)	**.270 (.013)**

Note: Data are Pearson's *r* (p-value).
Abbreviations. SD = standard deviation.

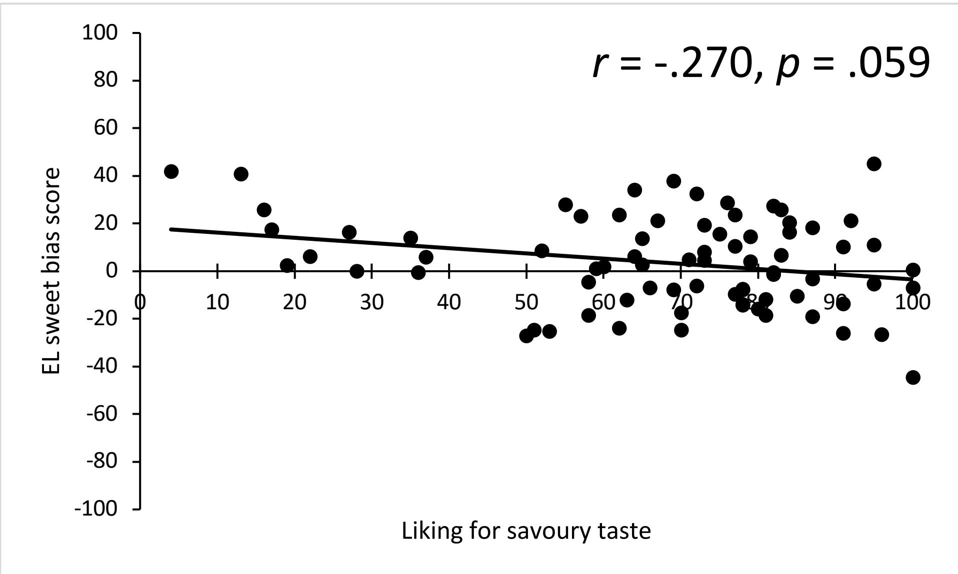

Figure 3.8 Association between explicit liking sweet bias score and liking for savoury taste.

3.5.2.2 Explicit wanting (EW)

Table 3.8 displays the results of Bivariate Pearson's analysis between EW taste preferences and test meal palatability ratings. Analysis identified positive associations between EW LFSA score and 'liking for savoury taste', as shown in Figure 3.9. No other significant associations were present.

Table 3.8 Correlations between EW taste preference and post meal palatability ratings.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sweet intensity (mm)	-.101 (.360)	-.070 (.526)	-.140 (.204)	-.147 (.182)	-.098 (.378)	-.017 (.875)
Sweet pleasantness (mm)	.166 (.131)	.105 (.341)	.157 (.154)	.121 (.274)	.012 (.917)	-.060 (.586)
Liking for sweet taste (mm)	.110 (.318)	.056 (.615)	.124 (.260)	.051 (.644)	-.037 (.737)	-.004 (.972)
Savoury intensity (mm)	-.012 (.914)	-.053 (.632)	.076 (.490)	.165 (.133)	.168 (.126)	.150 (.172)
Savoury pleasantness (mm)	-.101 (.363)	.024 (.830)	.038 (.733)	-.101 (.360)	.027 (.810)	.149 (.175)
Liking for savoury taste (mm)	-.187 (.089)	-.145 (.187)	-.050 (.650)	-.120 (.275)	-.015 (.891)	**.252 (.021)**

Note: Data are Pearson's *r* (p-value).
Abbreviations. SD = standard deviation.

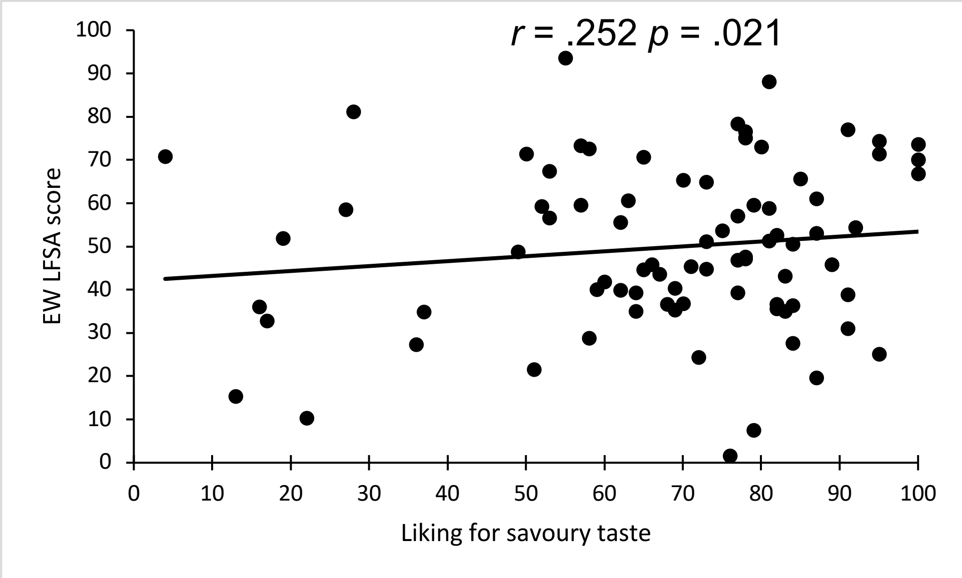

Figure 3.9 Associations between EW LFSA score and liking for savoury taste. Abbreviations. EW = explicit wanting. LFSA = low fat savoury.

3.5.2.3 Implicit wanting (IW)

Table 3.9 displays the results of Bivariate Pearson's analysis between IW taste preferences and post meal palatability ratings. Analysis identified positive associations between sweet bias and 'sweet pleasantness' (Figure 3.10), IW HFSW score and 'sweet pleasantness' (Figure 3.11) and IW LFSA score and 'liking for savoury taste' (Figure 3.12). No other significant associations were present

Table 3.9 Correlations between IW taste preferences and post meal palatability ratings.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sweet intensity (mm)	-.070 (.525)	-.092 (.403)	-.044 (.694)	-.055 (.619)	-.050 (.648)	.139 (.208)
Sweet pleasantness (mm)	**.241 (.027)**	.092 (.408)	**.239 (.029)**	.091 (.411)	-.181 (.099)	-.171 (.119)
Liking for sweet taste (mm)	.143 (.196)	.043 (.696)	.179 (.103)	.012 (.914)	-.164 (.136)	-.052 (.637)
Savoury intensity (mm)	.012 (.912)	-.074 (.504)	.026 (.812)	-.011 (.921)	-.113 (.308)	.080 (.467)
Savoury pleasantness (mm)	.049 (.655)	.009 (.939)	.153 (.165)	-.096 (.387)	-.171 (.119)	.081 (.466)
Liking for savoury taste (mm)	-.083 (.454)	-.130 (.238)	.018 (.873)	-.141 (.202)	-.164 (.135)	**.254 (.020)**

Note: Data are Pearson's *r* (p-value).
Abbreviations. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

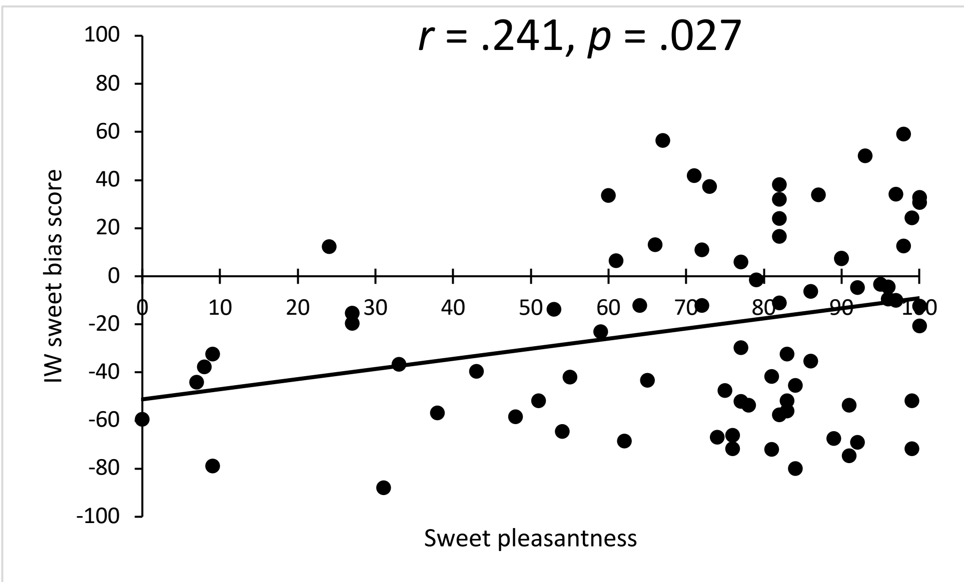

Figure 3.10 Association between IW sweet bias score and sweet pleasantness. Abbreviations. IW = implicit wanting.

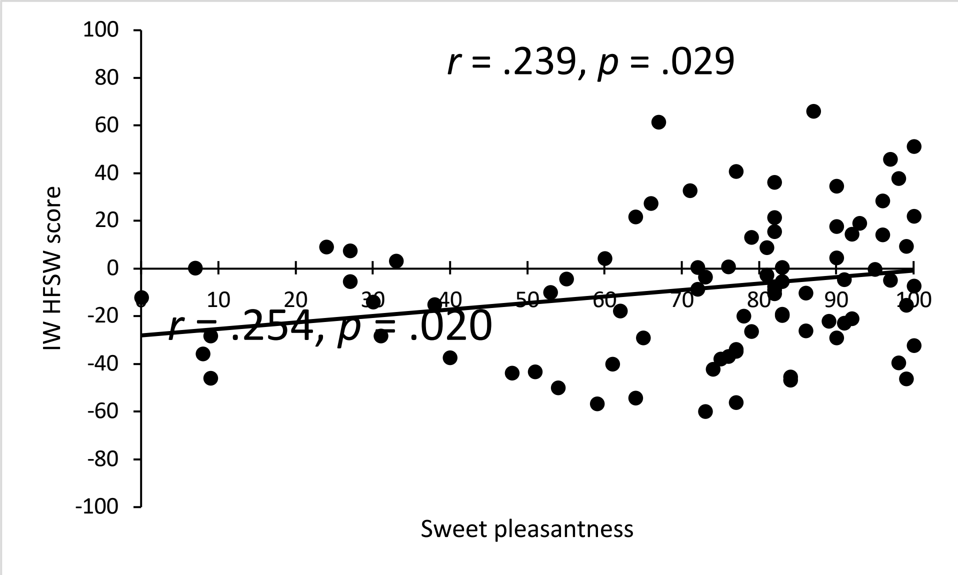

Figure 3.11 Association between IW HFSW score and sweet pleasantness. Abbreviations. IW = implicit wanting. HFSW = high fat sweet.

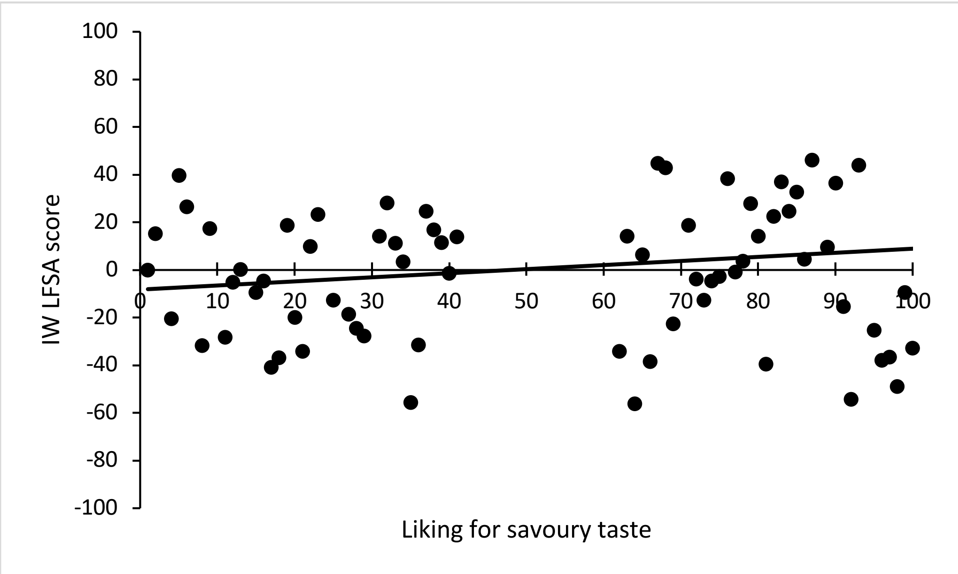

Figure 3.12 Association between IW LFSA score and liking for savoury taste. Abbreviations. IW = implicit wanting. LFSA = low fat savoury.

3.5.3 Taste preference and habitual food intake

Table 3.10 displays the descriptive statistics for habitual food intake across the entire sample, with absolute values (g) and intake as a percentage of total energy intake (%).

Table 3.10 Descriptive statistics of habitual food intake (*n*=82).

	Mean	Minimum	Maximum	SD
CHO (g)	203.87	76.35	324.22	46.61
CHO (%)	42.07	23.46	59.89	6.05
Protein (g)	72.22	40.76	122.44	20.31
Protein (%)	15.98	8.55	27.39	3.58
Fat (g)	75.13	24.55	139.77	20.54
Fat (%)	36.95	19.72	54.33	5.55
Sugar (g)	78.72	21.82	149.61	27.84
Sugar (%)	15.95	5.21	24.07	3.79
TEI (kcal)	1826.51	955.98	3059.45	404.27
TEI / RMR	1.33	0.68	1.94	0.28

Abbreviations. TEI = total energy intake. RMR = resting metabolic rate. SD = standard deviation.

3.5.3.1 Explicit liking (EL)

Table 3.11 displays the results of Bivariate Pearson's analysis between EL taste preference and habitual intake of sugar and fat in absolute values (g) and as a percentage of TEI (%) and TEI (kcal). Positive associations were present between EL HFSW score and fat intake (g), EL LFSW score and fat intake (g), EL HFSA score and fat intake (g), EL HFSA score and fat intake (%) and EL HFSW score and TEI (kcal). No other significant associations were present.

Table 3.11 Correlations between EL taste preferences and habitual intake of sugar, fat and TEI.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sugar (g)	.029 (.798)	.060 (.597)	.180 (.110)	.045 (.690)	.064 (.572)	.153 (.176)
Sugar (%)	.010 (.927)	.067 (.557)	.115 (.308)	-095 (.401)	-.074 (.517)	.088 (.439)
Fat (g)	.071 (.532)	.113 (.319)	**.225 (.045)**	**.238 (.033)**	**.282 (.011)**	.124 (.273)
Fat (%)	-.024 (.835)	.106 (.348)	.069 (.542)	.161 (.155)	**.309 (.005)**	.040 (.723)
TEI (kcal)	.087 (.444)	.055 (.630)	**.220 (.050)**	.193 (.086)	.160 (.155)	.140 (.214)

Abbreviations. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. TEI = total energy intake.

3.5.3.2 Explicit wanting (EW)

Table 3.12 displays the results of Bivariate Pearson's analysis between EW taste preferences and habitual intake of sugar and fat in absolute values (g) and as a percentage of TEI (%) and TEI (kcal). A negative association was present between EW HFSA score and sugar intake (%). No other significant associations were present.

Table 3.12 Correlations between EW taste preferences and habitual intake of sugar, fat and TEI.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sugar (g)	-.028 (.804)	-.063 (.578)	.055 (.628)	-.103 (.364)	-.135 (.233)	.152 (.180)
Sugar (%)	.041 (.719)	-.107 (.346)	.087 (.440)	-.036 (.749)	**-.221 (.049)**	.131 (.247)
Fat (g)	-.080 (.481)	.004 (.974)	.015 (.896)	-.135 (.232)	-.014 (.904)	.119 (.291)
Fat (%)	-.118 (.298)	-.042 (.713)	-.084 (.458)	-.082 (.471)	.055 (.628)	.113 (.319)
TEI (kcal)	-.050 (.660)	.012 (.919)	.036 (.748)	-.114 (.313)	-.031 (.785)	.093 (.410)

Abbreviations. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. TEI = total energy intake.

3.5.3.3 Implicit wanting (IW)

Table 3.13 displays the results of Bivariate Pearson's analysis between IW taste preferences and habitual intake of sugar and fat in absolute values (g) and as a percentage of TEI (%) and TEI (kcal). A negative association was present between IW HFSA score and sugar intake (%). No other significant associations were present.

Table 3.13 Correlations between IW taste preferences and habitual intake of sugar, fat and TEI.

	Sweet bias	Fat bias	HFSW	LFSW	HFSA	LFSA
Sugar (g)	-.028 (.804)	-.063 (.578)	.055 (.628)	-.103 (.364)	-.135 (.233)	.152 (.180)
Sugar (%)	.041 (.719)	-.107 (.346)	.087 (.440)	-.036 (.749)	**-.221 (.049)**	.131 (.247)
Fat (g)	-.080 (.481)	.004 (.974)	.015 (.896)	-.135 (.232)	-.014 (.904)	.119 (.291)
Fat (%)	-.118 (.298)	-.042 (.713)	-.084 (.458)	-.082 (.471)	.055 (.628)	.113 (.319)
TEI (kcal)	-.050 (.660)	.012 (.919)	.036 (.748)	-.114 (.313)	-.031 (.785)	.093 (.410)

Abbreviations. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. TEI = total energy intake.

3.5.4 Summary

Findings:

1. EL, EW and IW Sweet bias were positively associated with yoghurt intake (kcal).
1. EL sweet bias and LFSW were positively associated with yoghurt intake (%).
2. EL and EW LFSW and IW HFSW and IW Sweet bias were positively associated with 'sweet pleasantness' ratings.
3. EL HFSW was positively associated with habitual fat intake (g and %).
4. There was no association between sweet taste preference and habitual sugar intake.

Additional findings;

1. EL, EW and IW Sweet bias were negatively associated with risotto intake (kcal).
2. Wanting LFSA was negatively associated with yoghurt intake (%).
3. EL, EW and IW LFSA scores were positively associated with risotto intake (kcal) and EL LFSA was associated with TEI (kcal).
4. EL, EW and IW LFSA were positively associated with savoury palatability ratings.
5. EL LFSW and HFSA were positively associated with habitual fat intake (g and %) and TEI (kcal).
6. EW and IW HFSA negatively associated with lower sugar (%) intake.

3.6 Discussion

The current chapter aimed to examine whether specific preferences for sweet taste and sweet/fat combinations as measured by the LFPQ were associated with eating behaviour variables as measured by *ad libitum* intake of sweet (yoghurt), savoury (risotto) and total food, test meal palatability ratings and habitual intake of sugar, fat and TEI. Sweet bias scores were positively associated with yoghurt intake and negatively associated with risotto intake. Elevated LFSA preferences were positively associated with savoury palatability ratings. Sweet bias and fat bias scores were not associated with habitual sugar or fat intake, however, EL HFSW, LFSW and HFSA were positively associated with habitual fat intake, whereas EW and IW HFSA were negatively associated with habitual sugar intake.

3.6.1 Taste preference and *ad libitum* meal intake

EL, EW and IW sweet bias scores were positively associated with yoghurt intake (kcal) and (%), as well as EW and IW sweet bias displaying inverse associations with risotto intake (kcal) across the entire sample. This is interpreted as evidence displaying sweet taste preferences are associated with sweet food intake and inversely associated with non-sweet or taste dissimilar food intake. This thereby demonstrates a consistent association across different components of food reward with *ad libitum* test meal intake as well as supporting previous work which has shown taste preferences to be reflected in intake (Kaminski et al., 2000). Moreover, it demonstrates an inverse association between sweet taste preference and intake of a contrasting taste – in this instance savoury. This is a novel finding as associations between taste preferences and intake of contrasting foods is rarely examined.

More detailed examination of the association between sweet taste preference and sweet intake in an *ad libitum* test meal revealed a significant association between EL, EW and IW LFSW scores and yoghurt intake (%). This finding illustrates that higher LFSW preferences are associated with a similarly higher intake of an *ad libitum* LFSW food – a logical finding. Associations between both EW and IW HFSW scores and yoghurt intake (%) were also demonstrated – an unexpected finding as the food stimulus was not high fat. However, evidence has shown that fat content does not alter sweet perception (Bolhuis et al., 2018; Drewnowski et al., 1992) and although preferences for HFSW foods are often reported when examining sweet taste

(Drewnowski et al., 1992; Weingarten & Elston, 1991), the overriding sensation and preference remains that of sweet taste. Therefore, even though HFSW preference may be elevated, sweet taste may be the overriding preference. Future work may wish to examine whether this is true even when participants are provided with both a HFSW and LFSW food option. When only provided a LFSW food – as in the present study - it may be that participants opt for the next best alternative (i.e. a LFSW food), although if provided both options, the positive association between EW and IW HFSW preference and yoghurt (LFSW) intake may not be present.

In addition to this, a higher IW and EW sweet bias was associated with a lower intake of the savoury food, similarly, IW LFSA was negatively associated with yoghurt intake (kcal) and (%). From this it is concluded that wanting for sweet food can inversely impact intake of a non-sweet food item and vice versa. This is a novel finding as to our knowledge, no study to date has examined taste preferences relative to opposing tastes (i.e. sweet preference associations with savoury intake), however, differing food choice motives are known to impact food selection (Wadolowska, Babicz-Zielinska, & Czarnocinska, 2008) and so the inverse associations may reflect differences in motivation directed towards opposing tastes.

LFSA scores and intake of risotto were consistently positively associated, this is an intuitive finding as the risotto represented a LFSA food option. This finding supports previous work that has stated taste preferences are reflected in intake (Kaminski et al., 2000; Meiselman et al., 1974) and suggests a degree of consistency between liking and wanting in a single test meal, as well as further demonstrating the manner in which taste preference can influence intake of a contrasting food item.

It is of interest that there was not a significant association between any sweet taste preference measure and total intake in the *ad libitum* lunch meal. This suggests that sweet food preferences do not influence TEI over a single test meal consisting of a sweet and savoury food item. Sweet taste preference have been suggested to increase an individual’s risk of weight gain (Kant, 2000; Marriott, Olsho, Hadden, & Connor, 2010), however, providing LFSW foods, as is the case in the present protocol, this may not result in overconsumption. Sweetened fat is largely responsible for the increased intake of carbohydrate rich fat (Bolhuis et al., 2018) and large sources of dietary fat are provided by foods simultaneously high in free sugars, which are often consumed in excess (Cleobury & Tapper, 2014). Moreover, in a large French cohort a lower risk of obesity was associated with an increased sweet taste preference (Lampuré et al., 2016). This inverse association was shown to be driven by a higher intake of low-energy, (micro)nutrient-dense sweet foods – with this sub-group excluded the association become positive. These findings suggest that it is HFSW foods that increase an individual’s risk of overconsumption and weight gain. Moreover, LFSW foods such as yoghurt are not typically overconsumed, therefore it is not sufficient to claim that a sweet taste increases the risk of weight gain, rather it is the specific food types (i.e. HFSW foods) that are associated with a sweet taste preference that increase the risk of weight gain.

Taken together these findings demonstrate a positive association between EL, EW and IW sweet taste preference and intake of a sweet food, as well as a negative association between wanting for sweet and intake of a savoury food. In this way taste preference is shown to influence eating behaviour in a single meal. It is further concluded that a sweet taste preference does not predispose an individual to overconsume due to a lack of associations present between any sweet taste preference and TEI. It is plausible that whilst a sweet taste preference is associated with an increased sweet intake, the inverse association with savoury or taste dissimilar foods may prevent excess intake.

3.6.2 Taste preference and test meal palatability ratings

EL and EW sweet bias were not significantly associated with any test meal palatability ratings. However, IW sweet bias was positively associated with ‘sweet pleasantness’ ratings. Further exploration into the different sweet/fat combinations revealed that EL

LFSW was positively associated with ‘sweet pleasantness’ ratings also. These ratings were provided in response to a LFSW food option, and so this is an intuitive finding. As are the positive associations between EL, EW and IW LFSA scores and ‘liking for savoury taste’, as these ratings were provided in response to a LFSA food option.

The associations present between EL LFSW and ‘sweet pleasantness’ and IW HFSW and ‘sweet pleasantness’ may suggest differences in sweet/fat taste preference that are driven by differences in wanting. In nature sweet taste is indicative of an ample energy source (Tan & Tucker, 2019), therefore the association between a higher HFSW preference and a higher pleasantness of sweet foods may represent an increased unconscious motivation for energy-dense foods. Particularly given the fact that IW represents unconscious motivation (Finlayson et al., 2007).

Moreover, the positive associations present with explicit components may be due to desirability bias. In the present study individuals with overweight and obesity provided measurements prior to beginning a weight-loss trial – therefore these individuals represent a highly motivated group. For this reason, explicit preferences may be directed towards low-energy food options, whilst implicit (unconscious) processes remain directed at the energy-dense and highly rewarding foods. This conclusion supports evidence which has shown inverse associations between accuracy of reporting and social desirability scores (Herbert et al., 1997), with further evidence showing this discrepancy between reality and reported values becoming greater as a result of weight-loss interventions (Johnson, Friedman, Harvey-Berino, Gold, & McKenzie, 2005).

A further methodological issue to consider is that participants’ lay definitions of concepts used for palatability ratings may not match the experimenter’s definitions(Yeomans & Symes, 1999) and thus may not be valid. However, differences in the palatability ratings ‘liking’ and ‘pleasantness’ in response to both the sweet and savoury foods, suggests that these questions represented different concepts to participants.

'Sweet intensity' and 'savoury intensity' were both utilised as a proxy measure of taste sensitivity, as VAS responses were provided to standardised food items. The lack of an association between taste preferences and intensity ratings refutes work stating that taste preference and sensitivity are closely linked (Akella, Henderson & Drewnowski, 1997; Drewnowski & Henderson, 2001; Sartor 2011). However, these differences in the findings between previous literature and the current study may be due to differences in samples. Morbidly obese patients undergoing surgery have consistently demonstrated this association and the manner in which it can be altered following weight loss (Altun et al., 2016; Andriessen et al., 2018; Berthoud & Zheng, 2012), whereas the present study used overweight and lean participants; the association between subjective intensity ratings may only be observed in instances of extreme body weight. Alternatively, this may also reflect a possible methodological flaw with an oversimplification of taste sensitivity assessment in the present protocol – the usual method of assessing intensity provides participants with solutions or taste strips of varying intensities (Chamoun et al., 2019), rather than a single standardised taste as in the present protocol.

Overall, these findings demonstrate a positive association between EL LFSW preference and IW sweet bias, with 'sweet pleasantness' ratings for a LFSW food, as well as between LFSA taste preferences and 'liking for a savoury taste' in response to a LFSA food option. In this way taste preferences are shown to be associated with the subjective palatability of food.

3.6.3 Taste preference and habitual food intake

Neither EL, EW nor IW sweet bias scores were associated with habitual sugar intake (g) or (%), thereby failing to support our hypothesis. Similarly, EL, EW and IW fat bias scores were not associated with habitual fat intake. This fails to support previous associations between a higher liking for fat foods and an elevated consumption of dietary fats (Méjean et al., 2014) and suggests that sweet and fat taste preferences are not evident in habitual intake of sugar and fat in the present study.

Further exploration of these associations revealed positive associations between EL HFSW and HFSA and fat intake (g) – which is supportive of the Méjean and colleagues findings (2014). Moreover, as EL HFSW was also positively associated with TEI, speculation that HFSW foods are easily overconsumed and contribute to excess energy intake are supported (Lucas, 1989; Mela, 2006).

Furthermore, the positive association between EL LFSW and absolute fat intake suggests that an elevated liking for sweet foods even when absent fat, is associated with a higher intake of dietary fat. This is an unexpected finding and warrants further investigation. It seems counterintuitive that liking for LFSW foods would be positively associated with dietary fat intake. This may represent systematic error, however future work may wish to consider dietary sources as well as macronutrient intake as well in order to provide a more detailed understanding of unexpected associations such as this.

There was no association between EW sweet bias and fat bias scores and intake of sugar, fat or TEI. The lack of statistical findings within the sweet/fat combinations, further suggests that EW is not associated with habitual eating behaviours. A similar conclusion can be drawn for IW, with the exception of IW HFSA scores and sugar (%) intake which were positively associated. With the available data this cannot be explained, this is a further reason as to why future work may wish to examine specific foods or food categories within the diet, as a number of low fat food options are high in both sugar and salt – thereby maintaining a savoury taste (e.g. reduced fat peanut butter).

EW and IW HFSA were associated with less energy obtained from sugar, demonstrating that higher wanting for high fat, savoury (non-sweet) foods, there is a lower sugar consumption. This supports our conclusion that a sweet/savoury taste preference will be associated with intake of savoury/sweet foods respectively. Furthermore, it demonstrates that taste preferences may influence habitual intake of contrasting foods, similar to in a single meal.

In order to provide an estimation of the incidence of under-reporting total energy intake (kcal) was divided by the RMR figure provided by the GEM indirect calorimeter (kcal). The mean TEI/RMR within the present data set was 1.33, this is lower than what would be expected from even low physically active individuals, as previous research which stated a figure of 1.2 is indicative of being bed bound and motionless (Black, Coward, Cole & Prentice, 1996). The current findings therefore need to be taken with caution, however, under-reporting is known to be an issue with overweight participants (Gnardellis, Boulou, & Trichopoulou, 1998) with some studies noting a higher incidence of under-reporting in females than males (Vance, Woodruff, McCargar, Husted, & Hanning, 2009). This is not to discredit the findings, valuable insight into habitual dietary intake is still obtained, however conclusions must be drawn with caution and an awareness of the methodological issues.

Furthermore, although sugar is commonly included in foods to increase the sweet taste, with sweet products major contributors to sugar intake (Azaïs-Braesco et al., 2017) this does not mean that all sugar within the diet is sweet, it is possible for savoury foods to also maintain a relatively high amount of sugar (e.g. potatoes). A limitation in the use of MyFood24 is that this distinction between sweet and non-sweet sugars is not made, consequently although within the present thesis sugar intake within the diet is viewed as a sweet taste expression, this may not be entirely true. A consideration for future work may be to distinguish between free sugars included in food, which are more commonly included to increase sweet taste, and naturally occurring sugars. When distinguishing between liking for ‘natural sweetness’ and ‘added sugar’ previous work demonstrated that liking for natural sweetness was associated with a reduced obesity and type 2 diabetes risk, whereas added sugar was associated with an elevated risk (Lampuré et al., 2019, 2016). However, these previous studies examined associations between liking and obesity/diabetes risk; an elevated liking for any particular sweet taste may not have necessarily been associated with elevated intake of corresponding foods, which is a necessary relationship to examine within future work.

It has been previously suggested that taste sensations are not a major determination of food intake (Cooling & Blundell, 2001), supportive of this claim is the evidence that neither EW nor IW demonstrated consistent associations with habitual intake of sugar, fat or TEI. Therefore, from the present available data it is concluded a sweet taste preference is not expressed through habitual dietary intake of sugar – nor is a sweet taste preference associated with intake of dietary fat or TEI. However, it appears that EL for different sweet/fat combinations is associated with higher dietary fat intake although associations with sugar intake were absent.

3.6.4 Conclusion

An important limitation to consider is the large number of correlational analyses included with the present chapter. This increases the possibility of a type 1 occurring. This can be minimised by adjusting significance levels or alternatively it is possible to increase the sample size in order to improve the precision of the IV.

It can be concluded that EL, EW and IW sweet taste preferences are associated with food intake in a single test meal, with higher sweet taste preferences associated with higher intakes of a sweet food and a lower intake of a savoury food. More specifically, LFSA taste preference is associated with a higher subjective palatability and intake of LFSA food in a single meal. Moreover, sweet taste is associated with habitual dietary intake, through higher fat intake but not sugar intake and a savoury taste preference is associated with lower sugar intake.

Chapter 4 What is the role of body weight on sweet taste preference?

4.1 Aims

This chapter aims to identify whether overweight compared to lean participants differ in their sweet taste preferences and the expressions of these preferences through the intake and palatability of sweet compared to savoury foods and habitual dietary patterns. A food preference questionnaire (LFPQ) will be used to explore liking and wanting for sweet taste. A*d libitum* test meal intake with sweet and savoury components and subsequent palatability ratings as well as habitual dietary intake (MyFood24) of sugar, fat and total energy will be compared. For all comparisons, participants will be distinguished on the basis of BMI.

4.2 Introduction

The study of sweet taste preferences in obesity has exposed a complex issue. Liking for sweet – a commonly used method of defining sweet taste preference – is not universal and varies across different intensities (Iatridi et al., 2019b; Thompson, Moskowitz, & Campbell, 1977). Sensitivity to 6-n-Propylthiouracil (PROP) is associated with sweet liking, with PROP super-tasters more likely to be sweet dislikers (Yeomans, Tepper, Rietzschel and Prescott, 2007). Sweet liking can be described as four distinguishable patterns as shown in Figure 4.1 (adapted from Iatridi, Hayes, & Yeomans, 2019a; Iatridi et al., 2019b). These response patterns are characterised by either; a positive slope (green), an inverted U-shape (yellow), a negative slope (red) and a horizontal unchanging slope (grey). In addition to this, sweet taste preference tends to differ across different food types (e.g. chocolate, drinks or soup all differ in optimal concentrations), with peak preferred levels of sugar differing depending on both the individual and the food item (Conner et al., 1988) and has both genetic and environmental contributions (Keskitalo et al., 2008).

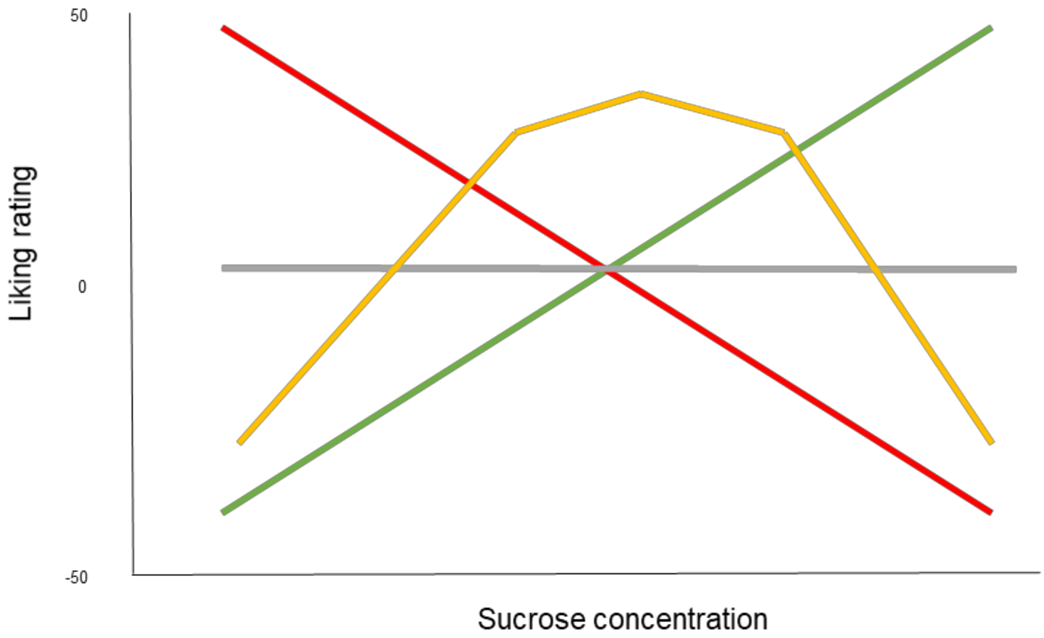

Figure 4.1 Four distinguishable patterns of sweet liking in response to sucrose concentration (Iatridi et al., 2019a, 2019b).

Sweetness is a potent psychobiological phenomenon, with high importance due to an association in nature with carbohydrates and energy (Tan & Tucker, 2019), meaning it is in human nature to be attracted to sweet tastes (Qian Yang, Kraft, Shen, MacFie, & Ford, 2019). Sweetness is also associated with a potent hedonic sensation and is capable of increasing the palatability of foods and encourage consumption. For this reason it can be expected that sweetness exerts positive effects on food choice and intake, with either a facilitative or permissive effect (Blundell & Finlayson, 2004).

Much of the early available data supports the conclusion that body weight does not affect liking for sweet taste (Drewnowki, Kurth & Rahaim, 1991). However, one study categorised women as either overweight or normal weight based on body fat measured using skinfolds. When participants were provided with four custard samples varying in sucrose content and thus sweetness intensity, it was found that those with a higher body fatness reported higher sucrose taste thresholds and a significantly increased liking for sweetness with increasing concentrations of sucrose (Ettinger, Duizer & Caldwell, 2012). Converseley, it has been shown that a higher body weight is associated with a higher sensitivity to and subjective strength of sweet tastes (Hardikar, Höchenberger, Villringer, & Ohla, 2017). These are important findings as sweet sensitivity has recently been demonstrated to be negatively correlated with sweet taste preferences (Chamoun et al., 2019). When taken with findings in patients with morbid obesity that have undergone laparascopic sleeve gastrectomy (Altun et al., 2016) the findings provided by Ettinger and colleagues suggest that as body fatness increases an individual's sensitivity to sweet stimuli rises in parallel, which occurs at the detriment of sweet taste preference. Although it has been suggest that an inverse U-shape relationship exists, with low sensitivity resulting in overeating as a form of self-medication at one end and at the other a downregulation occurring in response to chronic overconsumption (Davis & Fox, 2008).

Individuals with overweight habitually obtain a larger proportion of their dietary intake from sources high in fat (Hill, Melanson, & Wyatt, 2000; Miller et al., 1990) with recent evidence demonstrating that women with obesity prefer the sensations of fat to the sensations of sweet (Deglaire et al., 2015). When sugar and fat are integrated into a food item, the perception of fat is masked, leaving the perception of the sweet taste unaltered (Bolhuis, Costanzo, & Keast, 2018; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992), the elevated enjoyment of fatty taste in these foods is believed to be directly linked to an individual's %BF (Drewnowski, 1997). As a result, it is hypothesised that an elevated BMI is associated with an increased preference for foods characterised with a combination of high fat content and sweet taste (HFSW).

Common methods of assessing sweet taste preference are questionnaires (Chao, Grilo, White, & Sinha, 2014; Hodge, Bassett, Milne, English, & Giles, 2018; Kampov-Polevoy, Alterman, Khalitov, & Garbutt, 2006; Lampuré et al., 2019; McCrory et al., 1999), a time efficient method effective at gathering large amounts of data. Alternatively, the 'sip-and-spit' technique presents participants with a series of stimuli differing in concentrations, which the participant then rates on a VAS (Salbe, DelParigi, Pratley, Drewnowski, & Tataranni, 2004). However, previous work has considered taste preference to be synonymous with liking and not addressed wanting – in this case, the motivational attraction to sweet tasting food. These two concepts (liking and wanting) which underlie food reward (Berridge, 1996) are thought to be key in the development of taste preferences (Finlayson, King, & Blundell, 2007). Due to advances in human appetite, food preference and dietary intake methodologies which allow for quicker analysis of larger datasets, it is timely to revisit the differences between overweight and lean weight individuals regarding the sweet taste preference.

To our knowledge, this is the first study to utilise the LFPQ as a measure of sweet taste preference, considering differences in both liking and wanting in overweight and lean women. This builds on the already established evidence by providing comparisons of both liking and wanting for overall sweet preference as well as preferences for sweet/fat combinations. This will provide a more detailed understanding of overall sweet taste preferences as well as identify whether a HFSW preference is present in overweight women as suggest by the literature, and demonstrate the extent to which liking and wanting contribute to these preferences. Moreover, palatability ratings sweet and savoury meal components are used as measures of acute liking and pleasantness, with ‘sweet intensity’ and ‘savoury intensity’ ratings in response to a test meal utilised as a proxy measure of taste sensitivity.

Hypotheses;

1. There will be no between groups difference in EL, EW or IW sweet bias scores.
2. Overweight participants will display higher preferences for high fat sweet foods (HFSW) than lean participants.
3. The percentage intake of sweet food in a low fat meal consisting of sweet and savoury components will be higher in lean participants than overweight.
4. Overweight participants will display a lower sweet taste sensitivity than lean participants.
5. Overweight participants will report a greater portion of their free-living energy intake from fat, while lean individuals will obtain a greater proportion of their energy intake from carbohydrate/sugar.

4.3 Methods

Participants completed the LFPQ 2hours 45minutes after a standardised breakfast calculated at 25% of RMR. Upon completion an *ad libitum* test meal consisting of a sweet (yoghurt) and savoury (risotto) food items was provided, with the experimenter weighing foods immediately prior and after consumption. Test meal palatability and sweet/savoury intensity ratings were provided on VAS following ingestion of the test meal.

4.3.1 Statistical analyses

Data were visually explored using histograms and stem and leaf plots within SPSS to identify outliers. No extreme outliers were identified and all available data were included for each set of statistical analyses. Some data were unavailable as the present study was conducted within the remit of a larger research project, in which data collection was not complete, and in some cases data were missing – the sample size for each statistical test is clearly outlined. All data are displayed as means and standard deviations. Independent *t*-tests compared differences between EL, EW and

IW sweet bias and fat bias scores as well as different sweet/fat combinations (HFSW, LFSW, HFSA and LFSA) between overweight and lean groups. Following this a 2x2x2 mixed ANOVA with group (2 levels; overweight versus lean), sweet content (2 levels; sweet versus savoury) and fat content (2 levels; high fat versus low fat) was conducted to examine differences in taste preference across the entire sample, for EL, EW and IW. Independent *t*-tests compared differences in the *ad libitum* test meal intake and palatability ratings to the food items in this meal, as well as habitual food intake, between overweight and lean groups. Due to the manner in which sweet bias is calculated (sweet score minus savoury score) a negative sweet bias score is indicative of a savoury preference – therefore sweet bias is an indication of sweet relative to savoury preference. Finally, given the number of statistical analyses performed it was considered necessary to apply Bonferroni corrections in order to minimise the potential of a type-I error occurring. The Bonferroni corrections required the significance value of .05 to be divided by the number of tests being performed to provide a new significance level.

4.4 Results

4.4.1 Participant characteristics

Table 4.1 displays the participant characteristics and body composition in overweight and lean groups. Participants were matched for age and did not significantly differ. By design Overweight participants displayed a significantly higher BMI, and also significantly higher %BF and FM than the lean participants. No differences were seen for FFM.

Table 4.1 Participant descriptive statistics.

	Overweight (*n*=46)				Lean (*n*=40)				
	Mean	Minimum	Maximum	SD	Mean	Minimum	Maximum	SD	*P*
Age (years)	34.93	20.00	54.00	10.28	33.75	19.00	55.00	9.90	.589
Height (cm)	165.22	152.50	186.00	8.11	165.20	155.20	180.60	6.14	.986
Weight (kg)	79.97	60.59	112.37	11.62	59.73	48.36	74.50	6.17	< .001
BMI (kg/m^2)	29.17	25.43	34.57	2.40	21.86	18.87	25.66	16.65	< .001
Body fat %	41.42	28.10	55.9	5.16	27.67	13.40	38.70	4.98	< .001
Fat mass (kg)	33.44	20.26	59.35	8.17	16.62	6.47	23.72	3.77	< .001
Fat free mass (kg)	46.53	37.23	61.49	5.65	43.10	35.46	55.95	4.61	.003

Abbreviations. BMI = body mass index. SD = standard deviations.

4.4.2 Explicit liking (EL)

Table 4.2 displays the EL scores on each of the LFPQ food category and independent *t*-tests results, which did not find differences between overweight and lean participants.

Table 4.2 EL scores for overweight and lean participants.

	Overweight (*n* = 46)		Lean (*n* = 38)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
Sweet bias	-1.37	19.27	-9.71	22.27	1.839	.070
Fat bias	6.98	13.94	3.85	11.09	1.122	.265
HFSW	57.79	23.84	48.75	23.31	1.747	.084
LFSW	55.21	19.27	47.82	19.32	1.747	.084
HFSA	63.56	17.86	61.38	16.00	.585	.560
LFSA	52.18	19.12	54.61	17.90	-.597	.552

Abbreviations. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury. SD =

Within the ANOVA model, there was a statistically significant main effect of sweet content ($F(1,82) = 15.042$, $p < .001$) with sweet foods being more liked than savoury foods, and main effect of fat content ($F(1,82) = 5.970$, $p = .017$) with high fat foods being more liked than low fat foods. There was also a significant interaction effect between sweet content and fat content ($F(1,82) = 6.194$, $p = .015$).

Bonferroni post-hoc analyses revealed that EL was higher for LFSW than LFSA foods ($p < .001$) and HFSW than LFSW foods (p < .001). The difference between the means for HFSW and HFSA ($p = .405$) or LFSW and LFSA were not significant ($p = .499$).

There was no effect of group ($F(1,82) = 1.713$, $p = .194$). There was also no interaction between sweet content and group ($F(1,82) = 1.260$, $p = .265$), fat content and group

(F(1,82) = 3.382, p = .070) or sweet content and fat content and group (F(1,82) = .255, p = .615).

4.4.3 Explicit wanting (EW)

Table 4.3 displays the EW scores on each of the LFPQ food category and independent *t*-test results, which did not find any differences between overweight and lean participants.

Table 4.3 EW scores for overweight and lean participants.

	Overweight (*n*=46)		Lean (*n*=38)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
Sweet bias	-5.72	21.86	-12.05	21.56	1.329	.188
Fat bias	7.21	13.86	2.41	11.73	1.695	.094
HFSW	49.91	25.24	41.55	23.38	1.562	.122
LFSW	47.02	20.73	43.40	19.75	.814	.418
HFSA	59.95	17.89	57.85	16.78	.551	.583
LFSA	48.42	20.39	51.20	16.91	-.669	.505

Abbreviations. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Within the ANOVA model, there was a statistically significant main effect of sweet content (F(1,82) = 11.496, p < .001), with savoury foods being more wanted than sweet foods, and fat content (F(1,82) = 13.928, p = <.001) with high fat foods wanted more than low fat foods. There was also a significant interaction effect between sweet content and fat content (F(1,82) = 8.032, p = .006).

Bonferroni post-hoc analysis demonstrated that EW for LFSW was higher than LFSA (p < .001) and LFSW was higher than HFSW (p < .001). The difference between the means for HFSW and HFSA (p = .814) and LFSA and HFSA were not significant (p = .124).

There was not a statistically significant difference in EW between groups ($F(1,82) = .793$, $p = .376$). There was also not a statistically significant interaction effect of sweet content and group ($F(1,82) = 2.873$, $p = .094$), or fat content and group ($F(1,82) = 1.765$, $p = .188$) or between sweet content and fat content and group ($F(1,82) = .001$, $p = .982$).

4.4.4 Implicit wanting (IW)

Table 4.4 displays the IW scores on each of the LFPQ food category and independent *t*-tests results.

Table 4.4 IW for overweight and lean participants.

	Overweight (*n*=46)		Lean (*n*=38)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
Sweet bias	-16.46	38.95	-31.54	36.59	1.814	.073
Fat bias	16.81	25.80	6.70	27.54	1.734	.087
HFSW	-3.37	29.80	-14.78	26.67	1.831	.071
LFSW	-13.09	25.59	-16.76	27.30	.634	.528
HFSA	20.19	25.76	21.48	22.97	-.241	.810
LFSA	-3.72	25.53	10.06	30.00	-2.274	.026

Abbreviations. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Within the ANOVA model, there was a statistically significant main effect of sweet content ($F(1,82) = 16.266$, $p < .001$) with savoury foods wanted more than sweet foods, and main effect of fat content ($F(1,82) = 33.374$, $p < .001$) with high fat foods wanted more than low fat foods. There was also a significant interaction effect between sweet content and fat content ($F(1,82) = 4.008$, $p = .049$).

Bonferroni post-hoc analysis revealed that IW was higher for LFSW than LFSA ($p < .001$), LFSW was higher than HFSW ($p < .001$) and LFSA was higher than HFSA ($p < .001$). The difference between the mean for HFSW and HFSA ($p = .182$).

There was not a statistically significant interaction effect between sweet content and group ($F(1,82) = 3.008$, $p = .087$), or fat content and group ($F(1,82) = 3.292$, $p = .073$), or sweet content and fat content and group ($F(1,82) = .161$, $p = .689$).

IW is a forced choice procedure (i.e. relative preference) and so the mean at the individual level will always equal 0. Therefore, a test of between-subjects effects cannot be performed.

4.4.5 *Ad libitum* test meal intake

Table 4.5 displays the *ad libitum* test meal intake for a sweet food (yoghurt), savoury food (risotto), total intake and relative intake of sweet food (yoghurt divided by total intake), as well as independent *t*-test results. Overweight and lean participants did not differ on *ad libitum* test meal intake. Figure 4.2 displays the variation in intake of the test meal items and total test meal intake.

Table 4.5 *Ad libitum* test meal intake for overweight and lean participants.

	Overweight (*n*=46)		Lean (*n*=40)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
Yoghurt (kcal)	264.98	150.90	236.12	186.42	.793	.430
Risotto (kcal)	605.00	190.23	600.24	180.18	.119	.906
Total (kcal)	869.97	248.05	836.35	229.31	.649	.518
Sweet food intake (%)	29.47	14.45	27.11	16.75	.702	.484

Abbreviations. SD = standard deviation.

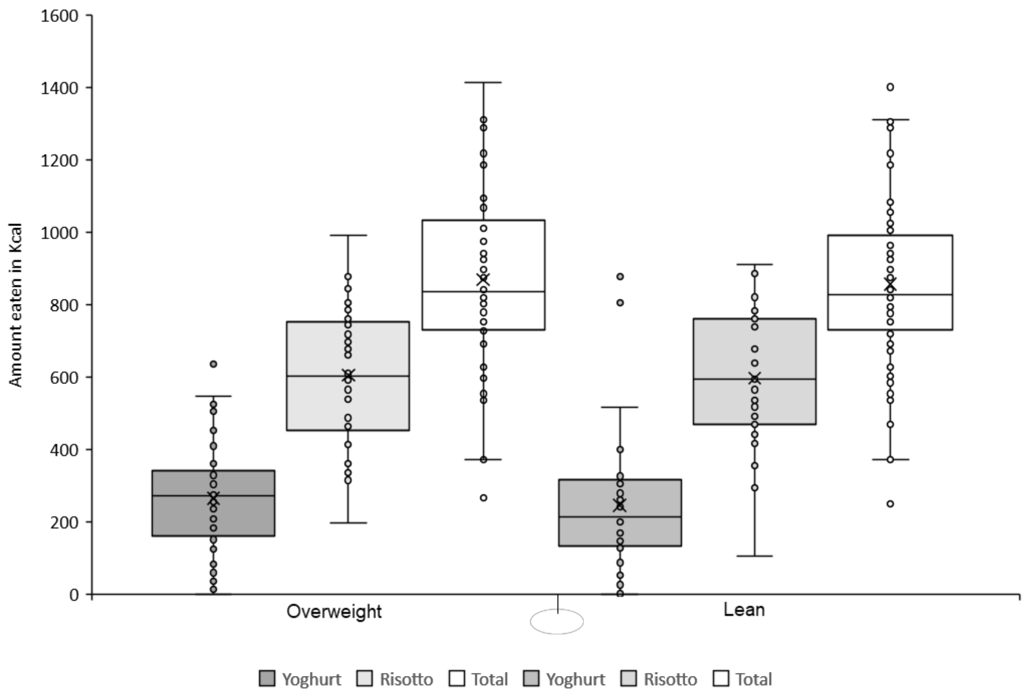

Figure 4.2 Variance in *ad libitum* test meal intake in overweight and lean weight participants.
Note. Upper whisker displays maximum value, lower whisker displays minimum value. The box displays the 1st and 3rd quartiles and the mean.

4.4.6 Test meal palatability ratings

Table 4.6 displays the test meal palatability ratings for the sweet (yoghurt) and savoury (risotto) foods, and independent *t*-test results. Overweight participants scored significant higher on ‘savoury pleasantness’ than lean participants, with a similar trend for ‘liking for a savoury taste’ and ‘savoury intensity’. There was no difference between overweight and lean participants’ responses to a sweet food item. Figure 4.3 displays the variation in test meal palatability ratings between participants.

Table 4.6 Test meal palatability ratings to the sweet (yoghurt) and savoury (risotto) foods for overweight and lean participants.

	Overweight (*n*=46)		Lean (*n*=40)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
Sweet intensity (mm)	71.28	20.45	74.05	22.05	-.604	.548
Sweet pleasantness (mm)	75.04	26.31	67.60	24.06	1.361	.177
Liking for sweet taste (mm)	73.09	26.90	64.10	24.77	1.603	.113
Savoury intensity (mm)	74.33	17.72	65.48	19.76	2.190	.031
Savoury pleasantness (mm)	76.41	16.23	64.48	19.56	**3.093**	**.003**
Liking for savoury taste (mm)	72.00	20.06	63.83	23.00	1.761	.082

Abbreviations. SD = standard deviation.

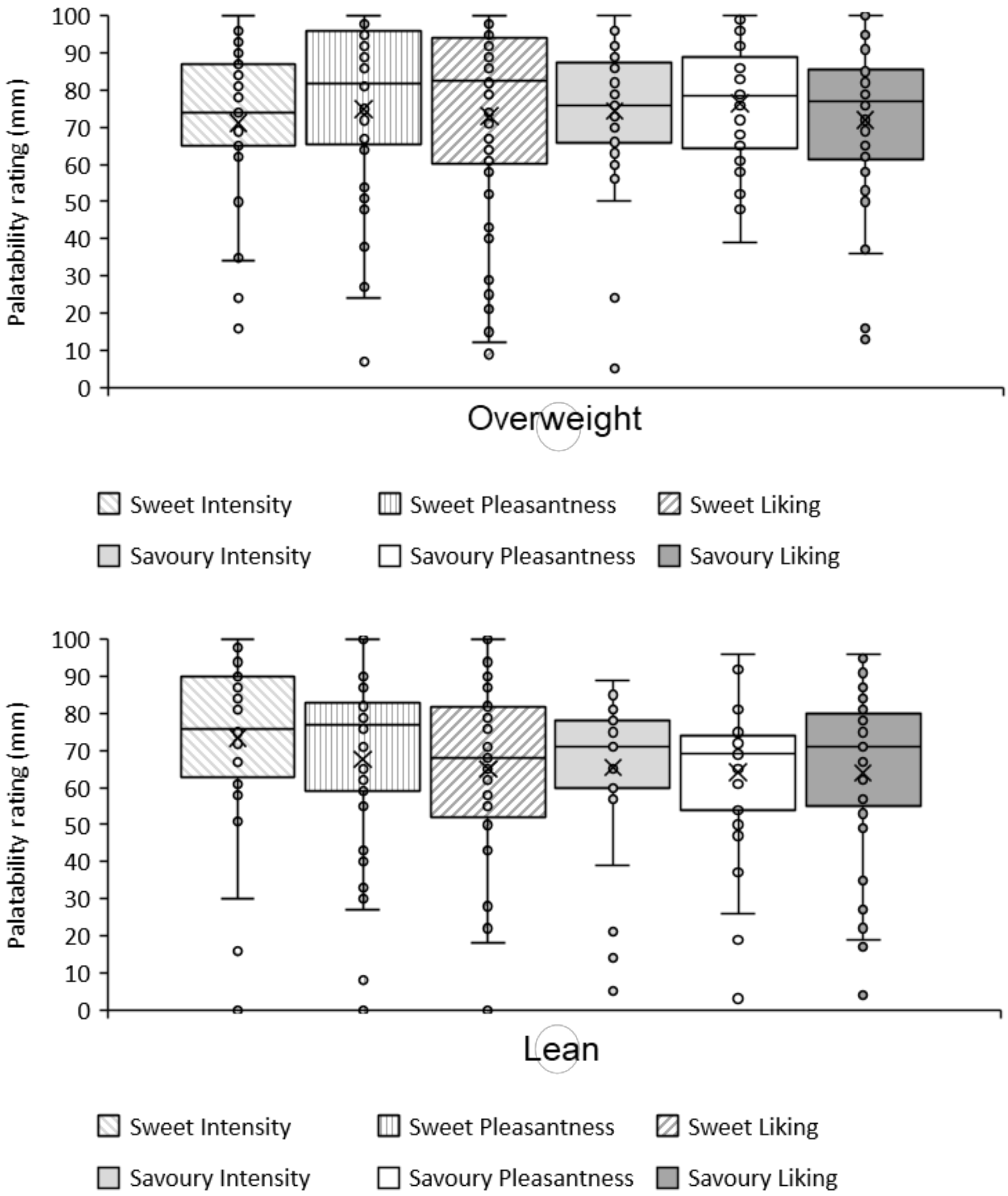

Figure 4.3 Variation within palatability ratings to sweet and savoury food items in the *ad libitum* test meal for overweight and lean participants.
Note. Upper whisker displays maximum value, lower whisker displays minimum value. The box displays the 1st and 3rd quartiles and the mean.

4.4.7 Habitual food intake

Table 4.7 displays the habitual intake in absolute terms (g) and as a percentage of total energy intake (%). Independent *t*-tests did not identify any differences between overweight and lean participants.

Table 4.7 Habitual intake for overweight and lean participants.

	Overweight (*n*=46)		Lean (*n*=36)			
	Mean	SD	Mean	SD	*t*-value	*p*-value
CHO(g)	206.79	51.69	200.14	39.60	.639	.525
CHO(%)	41.65	5.92	42.30	6.25	-.708	.481
Pro(g)	73.12	19.82	71.08	21.15	.450	.654
Pro(%)	15.89	3.43	16.10	3.79	-.262	.794
Fat(g)	77.58	18.91	71.77	22.27	1.316	.192
Fat(%)	37.83	5.28	35.83	5.77	1.632	.107
Sugar(g)	82.72	29.50	73.62	24.82	1.513	.143
Sugar(%)	16.45	4.03	15.32	3.41	1.346	.182
TEI (kcal)	1857.59	401.62	1786.79	409.84	.785	.435
EI/RMR	1.27	0.23	1.33	0.28	.426	.672

Abbreviations. CHO = carbohydrates. Pro = protein. SD = standard deviation. TEI = total energy intake.

4.4.8 Summary

Hypotheses;

1. No difference between overweight and lean participant's EL, EW or IW sweet bias.
2. No difference between overweight and lean participant's EL, EW or IW HFSW preference.
3. No difference between overweight and lean participant's *ad libitum* test meal intake.
4. No difference between overweight and lean participant's palatability ratings of a sweet food.
5. No difference in overweight and lean participant's habitual food intake.

Additional findings;

- No difference between overweight and lean participant's EL, EW or IW fat bias preferences.
- Higher preference for savoury foods over sweet foods, high fat foods over low fat foods and LFSW than LFSA across entire sample.
- Overweight participants had higher palatability ratings to a savoury food item than lean participants.

4.5 Discussion

The aim of the current chapter was to identify whether overweight compared to lean participants differed in their taste preferences and the expressions of these preferences through *ad libitum* and habitual intake, as well as test meal palatability ratings. No differences between groups were found for EL, EW or IW sweet or fat bias scores, *ad libitum* test meal intake of a sweet, savoury or total food, or habitual intake of sugar and fat. Overweight participants displayed higher palatability ratings to a savoury food item than lean participants and across the entire sample there was a higher preference for savoury over sweet foods and high fat over low fat foods.

4.5.1 Explicit liking (EL), explicit wanting (EW) and implicit wanting (IW) sweet, fat and sweet/fat combination preferences

The results of the present study do not demonstrate any differences between overweight and lean participant's liking and wanting for sweet, fat or different sweet/fat combinations (HFSW, LFSW, HFSA and LFSA). From these findings it can be concluded that sweet taste preference does not differ between overweight and lean women. The lack of between group differences between EL, EW or IW sweet bias scores between groups supports the hypothesis that overweight and lean women will not differ regarding their overall sweet taste preference. However, the lack of between group differences regarding EL, EW or IW HFSW preference does not support the hypothesis that overweight women will display a higher HFSW preference than lean women.

Evidence has previously shown a positive association between liking for fat sensations and BMI (Cox, Hendrie, & Carty, 2016; Deglaire et al., 2015), however, these previous claims are not supported within the present data. This hypothesis was developed due to the use of a large sample size and validated questionnaire in Deglaire's study (*n*=46,909), as well as evidence demonstrating reductions in taste sensitivity associated with an elevated BMI (Donaldson et al., 2009; Jayasinghe et al., 2017; Vignini et al., 2019). However, early work within the area found no difference in sweet taste preference with differing BMI (Cox, Perry, Moore, Vallis, & Mela, 1999), even when comparing lean (mean BMI = 21.8kg/m^2) and obese women (mean BMI = 38.0kg/m^2) (Pepino, Finkbeiner, Beauchamp, & Mennella, 2010). However, this lack of difference displayed by Pepino and colleagues was in response to a sweetened water solution, which may not be viewed as representative of a real food item. Alternatively, the incongruence between the current findings and previous work may be due to methodological differences between questionnaires (in the present study) and self-report pleasantness ratings (Cox et al., 1999) or stimuli presentation (Pepino et al., 2010).

Moreover, evidence which has shown overweight individuals display a greater HFSW preference is also not supported (Drewnowski, 1997; Drewnowski et al., 1992). These differences in findings may be due to methodological differences, with previous methods not providing comparisons against lean controls and thereby only providing information regarding obese or overweight participants. Secondly, participants were asked to write down their favourite foods, this may not be a true indication of taste preferences, whereas the LFPQ used within the present study was specifically designed as a method of assessing taste preferences. In this way, our conclusion is strengthened by the protocol employed, as the LFPQ is widely used in previous research and is deemed a reliable assessment of taste preferences (Cameron et al., 2014a; Griffioen-Roose, Hogenkamp, Mars, Finlayson, & de Graaf, 2012; Griffioen-Roose, Mars, et al., 2012). Further, this is a novel finding since the LFPQ has not been previously used to compare overweight and lean women's sweet taste preferences, with the majority of previous evidence defining sweet taste preference only as 'liking' and not 'wanting'.

The lack of difference between groups in IW is not in agreement with others who suggest that when differentiating participants based on BMI, differences in IW are more easily observed than liking (Mela, 2006), as an elevated BMI is associated with higher wanting (Saelens & Epstein, 1996; Volkow et al., 2011). However, the Saelens (1996) study assessed wanting via willingness to work for food reinforcers, whereas the LFPQ provides a covert, non-verbal indication of IW and is calculated using validated techniques (Dalton & Finlayson, 2014). Additionally, Saelen's and colleagues compared willingness to work for food reinforcers relative to sedentary activities, and although participants were offered 4 snack foods they were all HFSW. Therefore the available evidence provides little information regarding the motivation for different tastes. The use of the LFPQ strengthens our conclusion as it provides a more direct assessment of motivation for different taste preferences. Wanting for food may be higher in individuals with an elevated BMI relative to sedentary activities as suggested, but within the present study it is concluded that wanting for different sweet/fat combinations does not differ between overweight and lean individuals.

From the current findings there is no support to claims that sweet taste preference differs between overweight and lean women, similarly there is also no support to suggest differences exist for different sweet/fat combinations.

4.5.2 *Ad libitum* test meal intake

No differences were observed between overweight and lean participants in their intake of a sweet, savoury or total food in an *ad libitum* meal. There is little available evidence which has compared differences in overweight and lean weight participants' intake in an *ad libitum* test meal that has considered the taste elicited by the food stimuli. The majority of studies examining *ad libitum* intake focus on differences in energy density of foods selected, finding that individuals at high risk of obesity consume more energy dense foods than those individuals at a low risk of obesity (Kral et al., 2009), or alternatively focus on only one taste and its relative strength – noting that intake increased when savoury taste was strong rather than standard strength (Forde, van Kuijk, Thaler, de Graaf, & Martin, 2013). However, in the present study the foods were closely matched for energy content, and the novelty in its approach was that it considered the tastes of the test meal foods – sweet and savoury. This allows us to identify potential sources of excess calorie intake in a test meal (i.e. sweet or savoury food items), to better understand the relationship between sweet taste preference and weight.

The lack of a significant difference between overweight and lean participants in risotto intake may support previous evidence which has shown sweet and savoury preferences vary as a function of the time of day (de Graaf, Jas, Van der Kooy & Leenen, 1993). De Graaf and colleagues (1993) showed that savoury preferences are in line with traditional mealtimes, whereas sweet preferences are more evident through the day. Similarly, a recent study demonstrated that sweet intake is higher during snacking occasions throughout the day than meal times (van Langeveld et al., 2018). These studies may go some way to explaining the lack of differences in savoury intake between BMI groups, as intake was only examined in an *ad libitum* lunch meal.

Moreover, there was also no difference between groups in the intake of a sweet food, this fails to support the hypothesis that lean participants would have a higher intake of a sweet food in an *ad libitum* test meal. This hypothesis was developed in light of previous research which has demonstrated lean women display a preference for sweet foods absent fat (Drewnowski et al., 1985; Lampuré et al., 2016) and the fact the sweet stimulus in the *ad libitum* was characterised as LFSW. However, neither of these previous studies examined sweet intake in an *ad libitum* test meal, rather examining preferences in response to single stimuli presentation without the opportunity for participants to consume a non-sweet stimuli (Drewnowski et al., 1985) or self-reported habitual intake (Lampuré et al., 2016). It may be the case that liking for LFSW does not impact intake in a single test meal when provided with both a sweet and savoury food item. It may also be the case that associations between taste preference and intake are more evident within habitual intake studies rather than single meals – particularly when considering evidence which has shown savoury taste preferences to be more predominant within the context of traditional meal times (de Graaf, Jas, Van der Kooy & Leenen, 1993). Additionally, the two foods were carefully chosen to be representative of typical lunch foods consumed in everyday life, this represents a possible flaw in that both foods would not be typically overconsumed in real life and were both LFSW. This may have been insufficient for detecting differences in taste preference expressions via intake, as evidence suggests an association between an elevated BMI and HFSW preferences (Drewnowski, 1997; Drewnowski et al., 1985). It may be that overconsumption only occurs with high fat foods, due to the energy-density of fat facilitating a calorie surplus and weight gain

(Blundell & MacDiarmid, 1997). Future work may also wish to consider employing a buffet style meal with HFSW, LFSW, HFSA and LFSA food items included to provide participants with a greater degree of choice; this can be done with the same foods as in the present study, however it would require offering a high and low fat version of both.

Nonetheless, from the present findings it can be concluded that intake during an *ad libitum* test meal consisting of a sweet and savoury component, no differences between BMI groups were identified.

4.5.3 Test meal palatability ratings

‘Sweetness intensity’ and ‘savoury intensity’ as measured by VAS was utilised as a proxy measure of participant’s sensitivity to sweet and savoury taste. Participant groups did not differ in their sensitivity to either taste, disagreeing with work which states overweight individuals have lower taste sensitivity (Altun et al., 2016; Berthoud & Zheng, 2012; Hardikar et al., 2017; Vignini et al., 2019). For example, one study which used participants ranging from underweight (<18.5kg/m^2) to morbidly obese (>40kg/m^2) displayed a linear inverse association between BMI and taste sensitivity as measured by ‘Taste Strips’ (Fernandez-Garcia et al., 2017). However, a systematic review examining the influence of weight status on sensory attributes such as sensitivity concluded that there is no clear association between sweet sensitivity and BMI (Cox, Hendrie, & Carty, 2016), this was stated as a consequence of varying methodology within the area. It may be argued that methodology such as ‘taste strips’ for measuring taste sensitivity is a more robust and reliable method of assessing sensitivity compared to the test meal VAS performed in this study.

Overweight and lean participants did not differ in the palatability ratings to a sweet food item, which refutes our hypothesis and evidence stating that obese subjects report higher pleasantness’ ratings for sweet tastes (Sartor et al., 2011). This suggests that palatability of a sweet food does not differ with varying BMI. However, overweight participants displayed higher palatability ratings to a savoury food item than lean participants (although ‘liking for a savoury taste’ and ‘savoury intensity’ only approached significance levels); this supports evidence obtained from a large database (*n*=1,351) which states individuals with a higher BMI will enjoy savoury to a greater extent than lean counterparts (van Langeveld et al., 2018). However, the van Langeveld and colleagues study noted that energy intake of ‘salt, umami and fat’ (savoury) was higher during lunch and dinner, whereas intake of sweet foods was higher during snacking occasions. This may represent a possible flaw within the present protocol; if van Langeveld’s observations are correct this may mean that intake of a savoury or sweet food may differ depending on eating occasion (i.e. meal vs snack). This would be consequently missed within the present study as only a lunch test meal was utilised. Future studies may wish to consider providing opportunities to ingest snacks on assessment days in addition to consuming a test meal.

It can be concluded that subjective palatability of a sweet food does not differ between BMI groups, whilst overweight participants report greater palatability ratings to a savoury food compared to the lean group.

4.5.4 Habitual food intake

Habitual intake of protein, carbohydrates, fat and sugar, expressed as either an absolute value or as a percentage of TEI, or TEI (kcal) did not differ between overweight and lean participants. This refutes previous work which has shown that individuals with a higher BMI, obtain a higher percentage of energy from fat (Lovejoy & DiGirolamo, 1992; Hill et al., 2000) and also have a higher absolute fat intake. Consequently this refutes the hypothesis that habitual fat intake would be significantly greater for individuals with a higher BMI. With there being no difference in sugar intake between the two groups, the data suggests free sugars are not a vehicle for dietary fat intake (Emmett & Heaton, 1995), as if this were the case sugar and fat intake would be both elevated in overweight participants.

The immediate conclusion drawn is that overweight and lean women do not differ in their habitual dietary intake, with differences in BMI being explained by differences in physical activity levels – however, physical activity levels within the current data sample remain unknown. This thereby highlights a potential limitation in the present protocol in that energy balance is an equation with two sides, only one of which was assessed here. Furthermore, a limitation of this free-living measure of habitual intake is the degree of underreporting within the data. Evidence has shown both obese and non-obese women fail to report between meal snacks (Poppitt, Swann, Black, & Prentice, 1998) – as shown in the present data set with similar levels of under-reporting present. Retrospective dietary records have the disadvantage of measuring memory of past diet rather than diet itself (Krall, Dwyer, & Ann Coleman, 1988). Therefore, dietary recall relies on the participant's correct and accurate memory, as well as their willingness and motivation to truthfully and accurately report all intake. Available evidence highlights that underreporting is a serious and pervasive problem, particularly in women with overweight and obesity (Johnson, Friedman, Harvey-Berino, Gold, & McKenzie, 2005), however in the present study although under-reporting did occur, there was no difference between groups. In addition to this, there is evidence to suggest that the act of reporting food intake itself inadvertently reduces intake because of an increase in self-monitoring (Goris, Westerterp-Plantenga, & Westerterp, 2000). However, although on an individual basis it has been deemed to be an insufficiently valid measure, on a group basis it is regarded as satisfactorily valid (Karvetti & Knutts, 1985) and so the results should not be totally discredited for this reason – these findings still provide a valuable insight into habitual dietary patterns.

4.5.5 Conclusion

From the present findings it can be concluded that overweight and lean participant's sweet taste preferences (liking and wanting) do not differ as measured by LFPQ. Additionally, BMI groups did not differ in *ad libitum* test meal consisting of a sweet and savoury item, nor did they differ in their self-reported habitual intake. However, overweight participants showed higher palatability ratings to a savoury food, suggesting that liking and pleasantness to a savoury food is higher in these individuals.

Chapter 5 Does BMI moderate the association between sweet taste preference and eating behaviour variables?

5.1 Aims

Sweet taste preferences have been shown to affect eating behaviour variables, but few differences in sweet taste preference are evident amongst individuals with overweight compared to lean weight. Findings in the literature and the present thesis suggest that BMI may still be an important moderator of the relationship between sweet taste preferences and eating behaviour. The aim of the present chapter is to examine the status of BMI as a moderator, to provide a greater understanding of its role in sweet taste preferences and food intake.

5.2 Introduction

Available evidence within the literature, as well as the findings from chapter 3 of the current thesis, demonstrate associations between taste preferences and eating behaviour variables. Associations are present between self-reported food preferences and frequency of food consumption (Kaminski, Henderson, & Drewnowski, 2000). More specifically, a heightened sweet taste preference is positively associated with an elevated carbohydrate intake (Drewnowski, Henderson, Levine, & Hann, 1999) although the distinction between sweet and savoury carbohydrates was not made. Moreover, a large prospective study in a French population observed a positive association between liking for both sweet and fat and TEI (Lampuré et al., 2016). In addition to previous evidence, the present thesis noted positive associations between sweet taste preferences and intake of a sweet food in an *ad libitum* test meal, as well as inverse associations between HFSA preferences and habitual sugar intake. These findings show that lower liking and wanting for savoury taste should be considered alongside sweet preferences as risk factors for high sugar intake.

An elevated liking for sweetness has been considered a possible factor in the etiology of obesity (Frijters & Rasmussen-Conrad, 1982) with preferences for sweet differing between obese and lean participants (Bartoshuk, Duffy, Hayes, Moskowitz & Snyder, 2006; Sartor et al., 2011). An investigation into liking noted that participants with obesity (mean BMI = 34.08kg/m^2) relative to overweight counterparts (mean BMI = 27.76kg/m^2) reported a higher liking for energy-dense, sweet foods (Proserpio et al., 2015). Similarly, a higher BMI in women is associated with a higher preference for foods high in sugar and fat (Deglaire et al., 2015). The available evidence therefore demonstrates significant differences in overweight and lean women regarding their sweet taste preferences, implicating BMI and specifically body fat levels as influential in the determination of these differences (Drewnowski, 1997), although the exact strength of the influence BMI exerts over these differences remains unknown. Furthermore, the findings in this thesis suggest that (low) savoury preferences may also determine the selection and greater intake of sweet food and habitual sugar intake, a phenomenon that has had relatively little attention in the available literature.

It is believed that individuals with overweight and obesity possess distorted or weakened taste sensitivity which is responsible for an increased desire for food - consequently leading to excess intake (Donaldson, Bennett, Baic, & Melichar, 2009). Specifically, sweet taste thresholds have been established as lower in individuals with an elevated BMI (Fernandez-Garcia et al., 2017) and relative to lean participants, obese individuals perceive equally sweet solutions as weaker (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006) – this may suggest that lean individuals will provide a greater palatability rating relative to individuals with obesity in response to a sweet stimulus. While these differences may not always translate to differences in liking (Cox et al. 1999) or wanting for sweet taste (this thesis), this distorted sensitivity may result in a higher intake of food in order to provide sufficient hedonic reward (Davis & Fox, 2008). In this manner, distortions in taste thresholds may influence food choice and intake via an elevated BMI and diminished sweet taste sensitivity (but no difference in sweet preference), thereby producing an increased drive to ingest sweet foods in order to receive their rewarding benefits.

Given the fact that few differences are visible in sweet taste preferences when differentiating individuals based on BMI, but that BMI may cause distortion in sweet taste sensitivity, it remains plausible to hypothesise that BMI could affect the relationship between sweet taste preference and intake of sweet food. Specifically, it is predicted that the association between sweet taste preference and eating behaviour will be stronger at higher levels of BMI. The present chapter will firstly explore differences in the associations between taste preferences and eating behaviour variables in overweight compared to lean participants before formally testing, where theoretically and statistically appropriate, the moderating influence of BMI.

Hypotheses;

1. Associations between EL, EW and IW sweet bias scores and *ad libitum* intake of a sweet, savoury and total food will be moderated by BMI, with a stronger positive association at higher levels of BMI.
2. Associations between EL, EW and IW sweet bias scores and test meal palatability ratings of a sweet and savoury food items will be moderated by BMI, with a stronger positive association between sweet palatability at lower levels of BMI, and a stronger positive association between savoury palatability at higher levels of BMI.
3. Differences between EL, EW and IW sweet bias scores and habitual intake of sugar, fat and TEI will be moderated by BMI, with a stronger positive association between fat intake at higher levels of BMI.
4. The will be a positive association between HFSW preferences and habitual sugar and fat intake in overweight but not lean participants.

5.3 Methods

7 day food diaries were completed by all participants using MyFood24 prior to their assessment day. In the laboratory, participants completed the LFPQ 2hr 45minutes after a fixed energy breakfast meal (calculated at 25% of estimated energy requirements), and immediately prior to an *ad libitum* test meal, which consisted of a sweet (yoghurt) and savoury (risotto) food items. Foods were closely matched for energy density and provided in excess of consumption, foods were weighed by an experimenter immediately prior to and following consumption. Following the meal participants completed palatability ratings of both food items.

A full description of the study protocol and measures can be seen in Chapter 2.

5.4 Statistical analyses

Bivariate Pearson's analysis were conducted between sweet taste preference (EL, EW and IW sweet and fat bias and HFSW, LFSW, HFSA and LFSA) and intake of an *ad libitum* test meal and subsequent palatability ratings, as well as habitual intake of sugar and fat (g) and (%) in both overweight and lean participants separately.

Relationships of interest were explored via moderation analysis using PROCESS, a modelling tool for SPSS (Hayes, 2012). Two criteria were used to define relationships of interest. Firstly, any association involving a measure of sweet taste preference (sweet bias, HFSW or LFSW) or sweet intake, and secondly, the presence of a significant ($p \leq .05$) association in either or both groups. A formal moderation analysis was conducted with LFPQ scores (sweet bias, HFSW and LFSW scores) as the predictor variables, *ad libitum* intake of a sweet, savoury and total food, palatability ratings to a test meal and habitual intake of sugar, fat and TEI as the outcome variables, BMI was utilised as a continuous moderator variable. These variables were mean centred prior to analysis as recommended by Howell (2013). Significant moderation interactions were visualised using simple slopes analysis. BMI was centred to one SD below the mean labelled as 'Low' (21.81kg/m^2), the mean value labelled as ‘Mean’ (25.96kg/m^2) and one SD above the mean labelled as ‘High’ (30.12kg/m^2). The Johnson-Neyman technique probed significant interactions to identify values on the continuum at which point the effect of BMI became significant and non-significant ($p \leq .05$) (Johnson & Fay, 1950). In the interest of word limit, non-significant moderation interactions were not visualised.

5.5 Results

5.6 Descriptive statistics

Descriptive statistics for overweight and lean participants can be seen in section 3.5.

5.7 Taste preference and *ad libitum* test meal intake

5.7.1 Explicit liking (EL)

Table 5.1 and Table 5.2 display the results of Bivariate Pearson's analysis between LFPQ EL and *ad libitum* test meal intake for overweight and lean participants.

Table 5.1 Correlations between LFPQ EL preferences and *ad libitum* test meal intake in overweight participant

	Overweight (*n* = 46)							
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	**.366**	**.012**	.020	.893	.238	.110	-.013	.929
Fat bias	-.093	.540	-.026	.862	-.077	.613	-.037	.806
HFSW	.251	.092	**.296**	**.046**	**.379**	**.009**	.011	.944
LFSW	**.328**	**.026**	.218	.146	**.367**	**.012**	-.039	.795
HFSA	-.113	.453	.192	.201	.078	.605	-.057	.706
LFSA	.012	.939	**.367**	**.012**	.288	.052	.054	.721

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.2 Correlations between LFPQ EL preferences and *ad libitum* test meal intake in lean participants.

	Lean (*n* = 38)							
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.114	.503	**-.419**	**.010**	-.229	.173	.246	.142
Fat bias	.033	.844	-.148	.382	-.086	.612	.050	.768
HFSW	.028	.871	-.224	.183	-.149	.380	.130	.442
LFSW	.112	.511	**-.362**	**.027**	-.188	.266	.302	.070
HFSA	-.022	.990	.049	.772	.036	.833	.053	.757
LFSA	-.126	.456	.322	.052	.145	.393	-.167	.322

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

EL sweet bias was positively associated with yoghurt intake in overweight participants but not lean, although the overall moderation model showed no moderation effect of BMI (b = .0016, 95% CI [-.0044, .0077], t =.5298, p = .5978).

EL sweet bias was inversely associated with savoury food intake in lean participants but not overweight, the overall moderation model significantly predicted savoury food intake (b = .0391, 95% CI [.0003, .0118], t = 2.0976, p = .0391). Table 5.3 displays the model output. EL sweet bias score significantly predicted savoury food intake. The Johnson-Neyman technique showed EL sweet bias significantly predicts savoury food intake below a BMI value of 25.7517kg/m^2, with no moderation above this value. When values were plotted at one standard deviation above or below the mean (Figure 5.1) it can be seen that a low EL sweet bias score predicts lower savoury food intake at a one standard deviation below the mean.

Table 5.3 Moderation analysis between EL sweet bias and risotto intake**.**

BMI	*b*	95% CI	*t*	*p*
Low	.0475	-.0821, -.0130	-2.7390	.0076
Mean	-.0224	-.0459, .0012	-1.8908	.0623
High	.0028	-.0297, .0353	.1722	.8637

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = one SD below the mean. High = one SD above the mean.

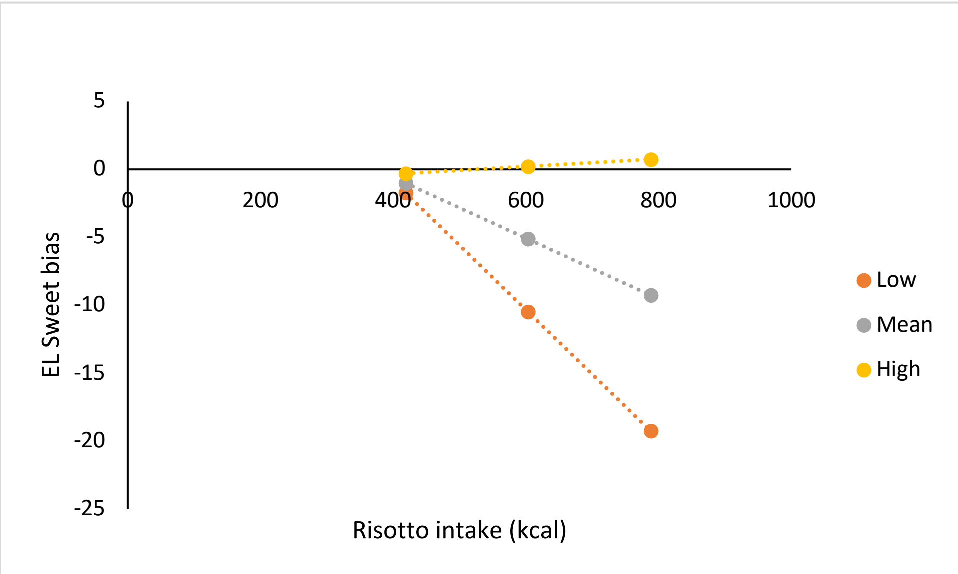

Figure 5.1 Visualisation of the moderation between EL sweet bias scores and risotto intake (kcal).
Abbreviations. EL = explicit liking.

EL HFSW was positively associated with savoury food intake in overweight participants but not lean. The overall moderation model significantly predicted savoury food intake (*b* = .0079, 95% CI [.0012, .0146], *t* = 2.3587, *p* = .0208), Table 5.4 displays the model output. The Johnson-Neyman technique showed EL HFSW significantly predicts savoury food intake below a BMI of 29.4468kg/m^2. When values are plotted at one standard deviation above or below the mean (Figure 5.2) it can be seen that one standard deviation below the mean, a higher EL HFSW predicts lower savoury food intake.

Table 5.4 Moderation analysis between EL HFSW and risotto intake.

BMI	*b*	95% CI	*t*	*p*
Low	-.0475	-.0821, -.0130	-2.7390	.0076
Mean	-.0224	-.0459, .0012	-1.8908	.0623
High	.0028	-.0297, .0353	.1722	.8637

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = one SD below the mean. High = one SD above the mean.

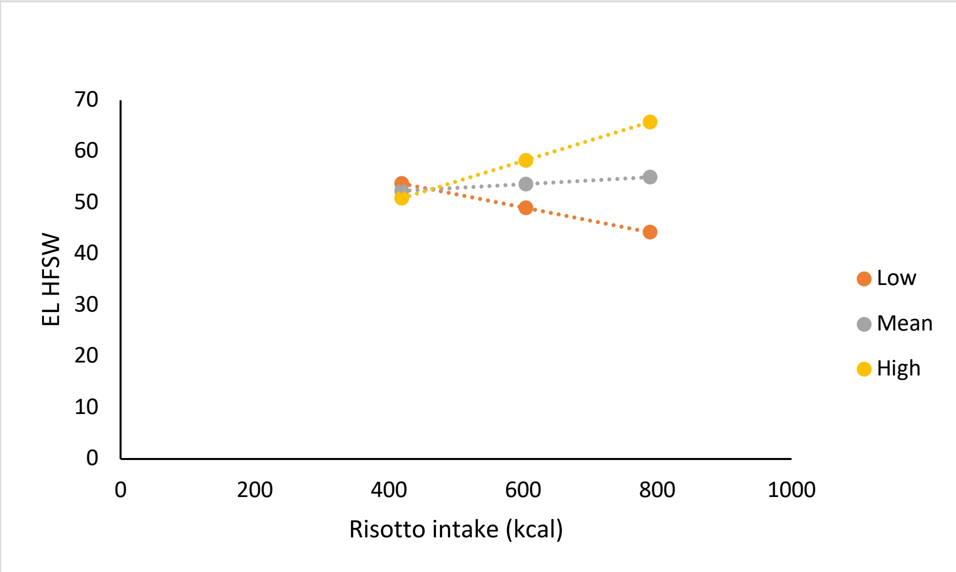

Figure 5.2 Visualisation of the moderation between EL HFSW and risotto intake (kcal). Abbreviation. EL = explicit liking. HFSW = high fat sweet.

EL LFSW was inversely associated with savoury food intake in lean participants but not overweight. The overall moderation model significantly predicted savoury food intake (b = .0126, 95% CI [.0015, .0124], t = 2.5526, p = .0126), Table 5.5 displays the model output. The Johnson-Neyman technique showed EL LFSW significantly predicts savoury food intake below the BMI 22.2988kg/m^2 and above 32.6740kg/m^2. When values are plotted at one standard deviation above and below the mean (Figure 5.3) it can be seen that elevated EL LFSW predicts lower savoury food intake at a BMI one standard deviation below the mean, and elevated EL LFSW predicts elevated savoury food intake one standard deviation above the mean.

Table 5.5 Moderation analysis between EL LFSW and risotto intake.

BMI	*b*	95% CI	*t*	*p*
Low	-0343	-.0670, .0015	2.5526	.0405
Mean	-.0052	-.0276, .0171	.4667	.6420
High	.0238	-.0070, .0546	1.5383	.1280

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = one SD below the mean. High = one SD above the mean.

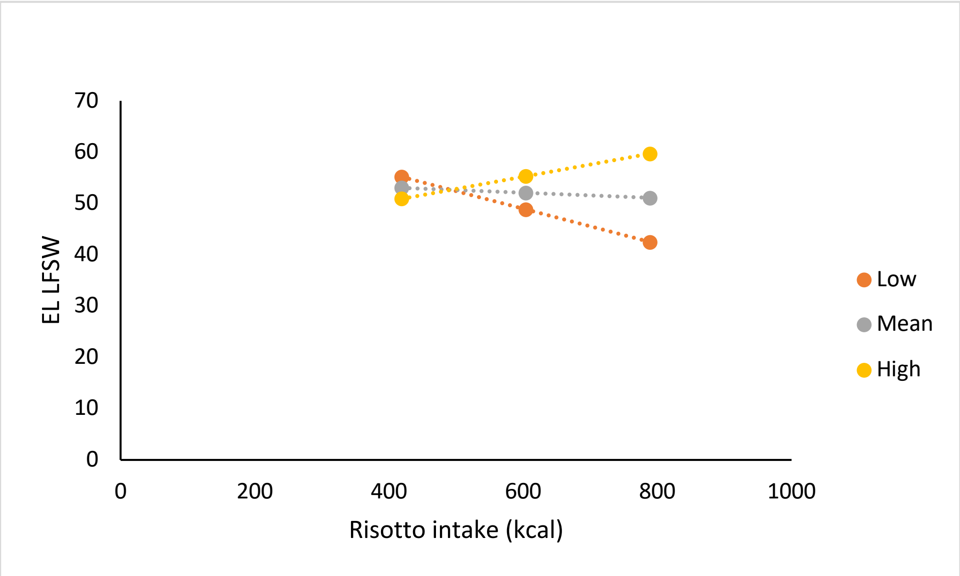

Figure 5.3 Visualisation of the moderation between EL LFSW and risotto intake (kcal). Abbreviations. EL = explicit liking. LFSW = low fat sweet.

EL LFSW and yoghurt intake were positively associated in overweight participants but not lean, although the overall moderation model was not significant (b = .0027, 95% CI [-.0029, .0084], t = .9591, p = .3405).

EL HFSW and TEI were positively associated in overweight participants but not lean. The overall moderation model significantly predicted TEI (b = .0058, 95% CI [.0005, .0110], t = 2.1984, p = .0308), Table 5.6 displays the output. The Johnson-Neyman technique showed that EL HFSW significantly predicted TEI above a BMI of 27.5666kg/m^2, with no moderation occurring below this value. When values are plotted at one standard deviation above and below the mean (Figure 5.4) it can be seen that an elevated EL HFSW predicts an elevated TEI one standard deviation above the mean.

Table 5.6 Moderation analysis between EL HFSW and TEI.

BMI	*b*	95% CI	*t*	*p*
Low	-.0109	-.0415, .0197	-.7106	.4794
Mean	.0131	-.0078, .0341	1.2466	.2162
High	.0372	.0073, .0671	2.4769	.0154

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = one SD below the mean. High = one SD above the mean.

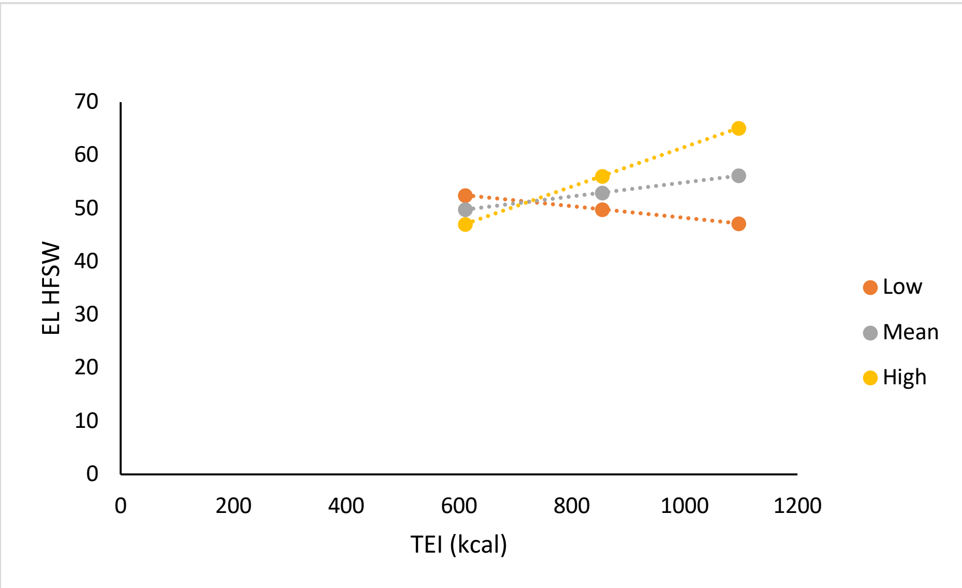

Figure 5.4 Visualisation of the moderation between EL HFSW and TEI (kcal).
Abbreviations. EL = explicit liking. HFSW = high fat sweet. TEI = total energy intake.

EL LFSW was positively associated with TEI in overweight participants but not lean. The overall moderation model significantly predicted TEI (*b* **=** .0047, 95% CI [.0004, .0090], *t* = 2.1893, *p* = .0315), Table 5.7 displays the output. The Johnson-Neyman technique showed that EL LFSW significantly predicted TEI above 28.2517kg/m^2, with no moderation below this value. When values are plotted at one standard deviation above and below the mean (Figure 5.5) it can be seen that an elevated EL LFSW predicts an elevated TEI one standard deviation above the mean.

Table 5.7 Moderation analysis between EL LFSW and TEI.

BMI	*b*	95% CI	*t*	*p*
Low	-.0108	-.0359, .0142	-.8606	.3920
Mean	.088	-.0084, .0260	1.0183	.3116
High	.0284	.0039, .0530	2.3101	.0235

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = one SD below the mean. High = one SD above the mean.

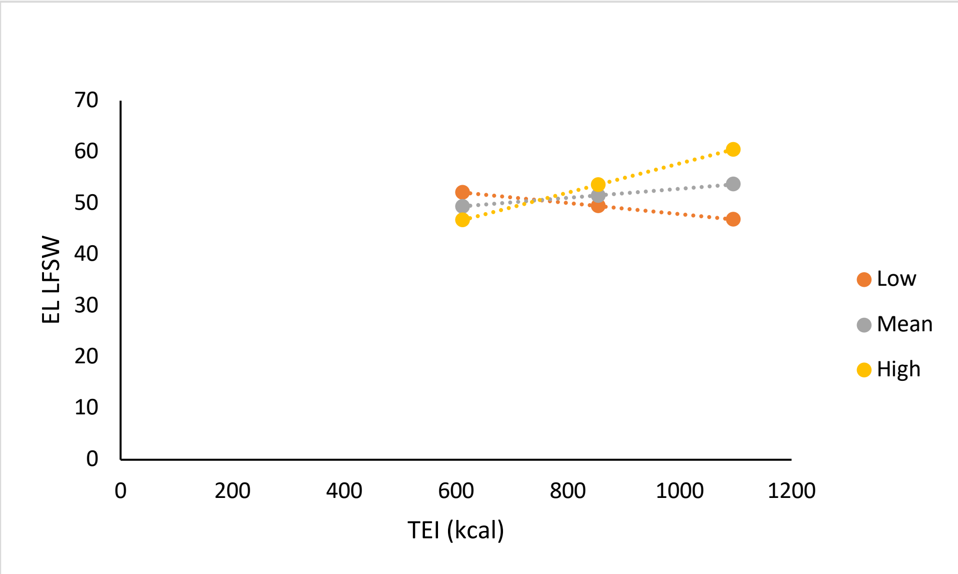

Figure 5.5 Visualisation of the moderation between EL LFSW and TEI (kcal). Abbreviations. EL = explicit liking. LFSW = low fat sweet. TEI = total energy intake.

5.7.1.1 Explicit wanting (EW)

Table 5.8 and Table 5.9 display the results of Bivariate Pearson's analysis between LFPQ EW and *ad libitum* test meal intake for overweight and lean participants. EW sweet bias and yoghurt intake were positively associated in overweight participants but not lean, however the overall moderation model was not significant (*b* = .0015, 95% CI [-.0048, .0079], *t* = .4776, *p* = .6343). A negative association was present between sweet bias and risotto intake (kcal) in lean participants but not overweight, although the overall moderation model was not significant (b = .0055, 95% CI [-.0005, .0115], t = 1.8321, p = .0707). There were no other significant associations in either overweight or lean participants.

Table 5.8 Correlations between LFPQ EW preferences and *ad libitum* test meal intake in overweight participants.

	Overweight (n = 46)							
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	**.325**	**.027**	-.113	.463	.111	.463	.053	.725
Fat bias	.086	.568	-.168	.264	-.076	.614	.113	.455
HFSW	.230	.124	.147	.328	.253	.090	.026	.866
LFSW	.287	.053	.103	.498	.253	.089	-.104	.493
HFSA	.003	.986	.127	.400	.099	.513	-.098	.518
LFSA	-.122	.418	**.418**	**.004**	.246	.099	-.102	.500

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.9 Correlations between LFPQ EW preferences and *ad libitum* test meal intake in lean participants.

	Lean (n = 38)							
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.167	.324	**-.433**	**.007**	-.198	.241	.291	.080
Fat bias	.026	.879	-.256	.126	-.175	.301	.116	.496
HFSW	.099	.561	-.300	.072	-.150	.376	.211	.211
LFSW	.118	.487	-.290	.082	-.127	.454	.236	.160
HFSA	-.058	.732	.041	.811	-.015	.929	-.018	.916
LFSA	-.094	.579	.315	.058	.165	.330	-.160	.344

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.1.2 Implicit wanting (IW)

Table 5.10 and Table 5.11 display the results of Bivariate Pearson's analysis between LFPQ IW and *ad libitum* test meal intake for overweight and lean participants. There was a positive association between IW sweet bias score and yoghurt intake (kcal) in lean participants but not overweight, although the overall moderation model was not significant (b = -.0050, 95% CI [-.0160, .0059], t = -.9131, p = .3640). There was an inverse association between IW sweet bias and risotto intake in lean participants but not overweight, although the overall moderation model was not significant (b = .0054, 95% CI [-.0052, .0160], t = 1.0144, p = .3135). There was a positive association between IW sweet bias and yoghurt intake (%) in lean participants but not overweight, although the overall moderation model was not significant (*b* = -.0463, 95% CI [-.1668, .0742], *t* = -.7651, *p* = .4465). There was an inverse association between IW LFSA and yoghurt intake (%) in lean participants but not overweight, although the overall moderation model was not significant (*b* = .0487, 95% CI [-.0401, .1374], *t* = 1.0919, *p* = .2782).

Table 5.10 Correlations between LFPQ IW preferences and *ad libitum* test meal intake in overweight participants.

	Overweight (*n* = 46)							
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.224	.134	-.182	.225	-.003	.983	-.010	.949
Fat bias	-.040	.794	-.090	.551	-.093	.538	.070	.642
HFSW	.159	.291	-.099	.513	.021	.891	.071	.638
LFSW	.157	.299	-162	.281	-.029	.847	-.098	.518
HFSA	-.224	.135	.024	.873	-.117	.437	-.012	.937
LFSA	-.117	.439	.254	.089	.124	.413	.027	.859

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.11 Correlations between LFPQ IW preferences and *ad libitum* test meal intake in lean participants.

Lean (*n* = 38)								
	Yoghurt intake (kcal)		Risotto intake (kcal)		Total intake (kcal)		Yoghurt (%)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	**.330**	**.046**	**-.380**	**.020**	-.027	.875	**.414**	**.011**
Fat bias	.050	.770	-.239	.155	-.142	.401	.153	.365
HFSW	.156	.357	-.255	.127	-.070	.678	.247	.140
LFSW	.292	.080	-.261	.118	.033	.847	.314	.058
HFSA	-.122	.472	.012	.944	-.088	.605	-.105	.537
LFSA	-.310	.062	**.454**	**.005**	.100	.556	**-.424**	**.009**

Note: Data are Pearson's *r* (p-value). *$p \leq .001$. Abbreviations. LFPQ = Leeds Food Preference Questionnaire. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.2 Taste preference and test meal palatability ratings

5.7.2.1 Explicit liking (EL)

Table 5.12 and Table 5.13 display the results of Bivariate Pearson's analysis between LFPQ EL preferences and test meal palatability ratings for overweight and lean participants. A positive association between HFSW and 'savoury pleasantness' was present in overweight participants but not lean, the overall moderation model significantly predicted 'savoury pleasantness' (b = .0809, 95% CI [.0127, .1491], t = 2.3601, p = .0207). Table 5.14 displays the model output. The Johnson-Neyman post-hoc analysis showed EL HFSW predicted 'savoury pleasantness' up to a BMI of 30.80kg/m^2 (below 1SD above the mean). with no moderation below this value. When values are plotted at one standard deviation above or below the mean (Figure 5.6) it can be seen that an elevated EL HFSW predicts a higher 'savoury pleasantness' rating with a high BMI.

Table 5.12 Correlations between LFPQ EL preferences and test meal palatability ratings for overweight participants (*n*=46).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.013	.929	.270	.069	.276	.063	.004	.980	.034	.823	-.006	.968
Fat bias	.-.037	.806	.045	.765	.015	.923	.069	.651	.229	.126	-.006	.968
HFSW	.011	.944	.244	.102	.201	.181	.222	.139	**.316**	**.033**	.132	.381
LFSW	-.039	.795	.175	.243	.189	.208	.141	.349	.034	.825	.003	.982
HFSA	-.057	.706	-.067	.658	-.083	.584	.202	.179	.178	.236	.158	.293
LFSA	.054	.721	-.001	.993	-.039	.798	.222	.138	.192	.200	**.318**	**.031**

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EL = explicit liking, HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.13 Correlations between LFPQ EL preferences and test meal palatability ratings for lean participants (*n*=30).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.276	.093	-.010	.953	-.156	.350	-.121	.470	**-.358**	**.027**	**-.356**	**.028**
Fat bias	-.272	.099	-.271	.100	-.241	.146	-.318	.052	**-.371**	**.022**	-.288	.079
HFSW	-.268	.104	.023	.891	.015	.927	-.030	.860	-.313	.056	-.278	.091
LFSW	-.160	.337	.241	.145	.018	.916	.165	.323	-.240	.146	**-.336**	**.039**
HFSA	.003	.984	.117	.485	.072	.670	.147	.379	-.049	.769	-.110	.511
LFSA	.164	.325	.210	.206	**.363**	**.025**	.309	.059	.267	.105	.260	.115

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.14 Moderation analysis between EL HFSW and 'savoury pleasantness' ratings.

BMI	*b*	95% CI	*t*	*p*
Low	-.3009	-.6924, .0907	-1.5292	.1302
Mean	.0385	-.2342, .3111	.2807	.7797
High	.3778	-.0211, .7767	1.884	.0631

Abbreviations. BMI = body mass index (kg/m^2). SD = standard deviation.
Note: Low = 1 SD below the mean. High = 1 SD above the mean.

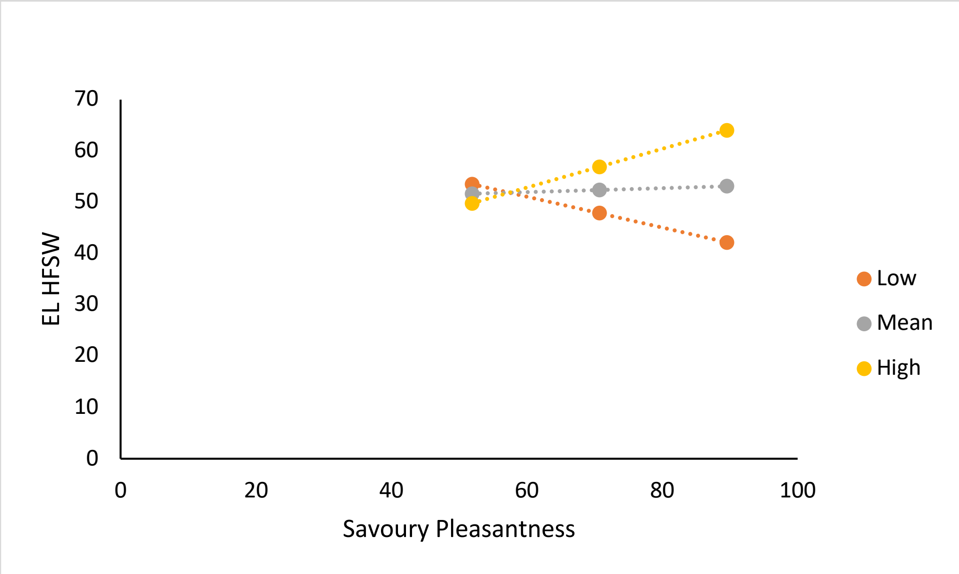

Figure 5.6 Visualisation of the moderation between EL HFSW and 'savoury pleasantness'.
Abbreviations. EL = explicit liking. HFSW = high fat sweet.

EL sweet bias was inversely associated with 'savoury pleasantness' in lean participants but not overweight, although the overall moderation model showed was not significant (*b* = .0500, 95% CI [-.0093, .1092], *t* = 1.6787, *p* = .0971). EL sweet bias was inversely associated with 'liking for savoury taste' in lean participants but not overweight, although the overall model was not significant (*b* = .0301, 95% CI [-.0215, .0817], *t* = 1.1623, *p* = .2486).

EL LFSW was inversely associated with 'liking for savoury taste' in lean participants but not overweight, although the overall moderation model was not significant (*b* = .0233, 95% CI [-.0341, .0807], *t* = .8079, *p* = .4216).

EL LFSA was positively associated with ‘liking for sweet taste’ in lean participants but not overweight, although the overall moderation model was not significant (b = -.0284, 95% CI [-.0663, .0095], t = -1.4896, p = .1403).

5.7.2.2 Explicit wanting (EW)

Table 5.15 displays the results of Bivariate Pearson’s analysis between LFPQ EW preferences and test meal palatability ratings for overweight participants. Table 5.16 displays the results of Bivariate Pearson’s analysis between LFPQ EW preferences and test meal palatability ratings for lean participants.

There were no significant positive associations for either overweight or lean participants and so no moderation analysis was performed.

Table 5.15 Correlations between LFPQ EW preferences test meal palatability ratings for overweight participants (*n*=46).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.053	.725	.253	.090	.264	.076	.097	.520	-.019	.900	-.171	.255
Fat bias	.113	.455	.198	.188	.108	.477	.048	.751	.122	.419	-.110	.468
HFSW	.026	.866	.170	.259	.171	.255	.210	.160	.166	.269	.005	.975
LFSW	-.104	.493	.099	.512	.146	.333	.256	.086	-.111	.463	-.122	.419
HFSA	-.098	.518	-.041	.785	-.070	.644	.215	.152	-.011	.944	-.017	.910
LFSA	-.102	.500	-.195	.193	-.144	.340	.124	.413	.144	.341	.264	.076

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury

Table 5.16 Correlations between LFPQ EW preferences and test meal palatability ratings for lean participants (*n*=30).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.257	.120	.003	.985	-.156	.350	-.206	.216	-.307	.060	-.279	.090
Fat bias	-.284	.084	-.108	.520	-.109	.514	-.219	.076	-.238	.150	-.292	.075
HFSW	-.318	.052	.083	.618	-.011	.949	-.161	.335	-.226	.172	-.182	.248
LFSW	-.185	.267	.123	.463	-.120	.471	.030	.859	-.173	.299	-.165	.323
HFSA	-.086	.607	.065	.698	-.018	.916	.096	.566	.025	.882	-.040	.812
LFSA	.084	.616	.186	.263	.260	.115	.242	.144	.244	.140	.292	.075

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.2.3 Implicit wanting (IW)

Table 5.17 displays the results of Bivariate Pearson's analysis between LFPQ IW preferences and test meal palatability ratings for overweight participants. Table 5.18 displays the results of Bivariate Pearson's analysis between LFPQ IW preferences and test meal palatability ratings for lean participants.

No associations were present which met the a priori moderation criteria.

Table 5.17 Correlations between LFPQ IW preferences and *ad libitum* test meal palatability ratings for overweight participants (*n*=46).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.078	.607	.308	.037	.272	.067	-.078	.607	.028	.853	-.109	.473
Fat bias	.070	.642	.067	.660	.002	.990	.153	.311	.106	.481	-.075	.618
HFSW	.071	.638	.279	.060	.211	.160	.033	.829	.271	.068	.044	.770
LFSW	-.098	.518	.145	.338	.169	.261	-.157	.299	-.273	.066	-.217	.148
HFSA	-.012	.937	-.256	.086	-.242	.106	.115	.446	-.207	.168	-.127	.401
LFSA	.027	.859	-.212	.157	-.171	.255	.003	.986	.166	.270	.294	.048

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

Table 5.18 Correlations between LFPQ IW preferences and *ad libitum* test meal palatability ratings for lean participants (*n*=30).

	Sweet intensity		Sweet pleasantness		Liking for sweet taste		Savoury intensity		Savoury pleasantness		Liking for savoury taste	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.107	.521	.090	.593	-.119	.476	.013	.99	-.069	.682	-.149	.373
Fat bias	-.236	.153	.063	.705	.023	.893	**-.401**	**.013**	-.217	.100	**.641**	**< .001**
HFSW	-.152	.363	.120	.472	.058	.730	-.086	.610	-.105	.529	-.101	.545
LFSW	.004	.979	.002	.989	-.216	.192	.101	.547	.011	.949	-.100	.550
HFSA	-.107	.522	-.064	.704	-.040	.810	**-.381**	**.018**	-.138	.409	-.207	.212
LFSA	.213	.199	-.060	.719	.176	.290	.276	.093	.189	.255	**.304**	**.037**

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.3 Taste preference and habitual intake

5.7.3.1 Explicit liking (EL)

Table 5.19 displays the results of Bivariate Pearson’s analysis between LFPQ EL preferences and habitual intake for overweight and lean participants.

EL HFSW was positively associated with fat intake (%) in lean participants but not overweight, although the overall moderation model was not significant (b = .0289, 95% CI [-.2199, .2777], t = .2312, p = .8178). EL LFSA and sugar intake (g) were positively correlated in lean participants but not overweight, although the overall moderation model was not significant (b = -.0365, 95% CI [-.0741, .0010], t = 1.9393, p = .0562). EL LFSA and sugar intake (%) were positively correlated in lean participants but not overweight, although the overall moderation model was not significant (b = -.2432, 95% CI [-.5080, .0151], t = -1.8770, p = .0644).

Table 5.19 Correlations between LFPQ EL preferences and habitual intake.

	Overweight (*n*=46)										Lean (*n*=30)									
	Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)		Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.187	.214	.215	.151	.132	.383	-.072	.634	.159	.290	-.249	.156	-.336	.052	-.028	.873	-.040	.824	-.016	.929
Fat bias	.150	.319	.164	.276	.177	.239	.179	.235	.088	.562	-.159	.370	-.168	.342	.003	.988	-.035	.846	-.014	.939
HFSW	.266	.074	.222	.068	.272	.068	.032	.865	.277	.063	-.017	.923	-.123	.487	.142	.422	.070	.696	.124	.486
LFSW	.103	.495	-.031	.836	.263	.077	.041	.785	.262	.078	-.109	.539	-.271	.122	.181	.305	.263	.133	.083	.641
HFSW	.027	.859	-.138	.360	.280	.059	.262	.079	.179	.233	.140	.430	.056	.753	.305	.080	**.406**	**.017**	.132	.458
LFSA	.034	.822	-.059	.695	.077	.612	-.018	.904	.120	.427	**.428**	**.011**	**.415**	**.015**	.225	.201	.170	.337	.194	.271

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EL = explicit liking. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.3.2 Explicit wanting (EW)

Table 5.20 displays the results of Bivariate Pearson's analysis between LFPQ EW preferences habitual intake for overweight and lean participants.

EW sweet bias and sugar intake (g) were inversely associated in lean participants but not overweight, although the overall moderation model was not significant (*b* = .0202, 95% CI [-.0259, .0662], *t* = .8721, *p* = .3859). EW sweet bias and sugar intake (%) were inversely associated in lean participants but not overweight, although the overall moderation model was not significant (*b* = .1754, 95% CI [-.1423, .4931], *t* = 1.0996, *p* = .2750). EW LFSA and sugar intake (g) were positively associated in lean participants but not overweight, although the overall moderation model was not significant (*b* = -.0340, 95% CI [-.0725, .0045], *t* = -1.7593, *p* = .0825). EW LFSA and sugar intake (%) were positively associated in lean participants but not overweight, although the overall moderation model was not significant (*b* = -.2315, 95% CI [-.4982, .0352], *t* = -1.7289, *p* = .0879).

Table 5.20 Correlations between LFPQ EW preferences and habitual intake.

	Overweight (*n*=46)										Lean (*n*=30)									
	Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)		Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	.056	.710	.158	.294	.007	.965	.036	.811	-.002	.989	**-.341**	**.048**	**-.389**	**.023**	-.095	.594	-.074	.677	-.081	.648
Fat bias	.129	.394	.125	.406	.077	.611	-.030	.846	.097	.521	-.198	.262	-.193	.275	-.031	.861	-.063	.723	-.040	.823
HFSW	.095	.529	.134	.373	.121	.422	.049	.746	.095	.531	-.145	.413	-.191	.279	.027	.880	-.053	.766	.036	.838
LFSW	-.051	.735	-.090	.553	.158	.295	.147	.330	.074	.624	-.291	.095	-.322	.063	.016	.927	.176	.320	-.090	.613
HFSA	-.029	.850	-.200	.183	.234	.117	.192	.202	.164	.277	-.038	.830	-.004	.983	.136	.443	.287	.099	-.030	.866
LFSA	-.030	.844	-.088	.560	.091	.549	.120	.429	.054	.723	**.420**	**.013**	**.415**	**.015**	.196	.267	.075	.672	.198	.262

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. EW = explicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.3.3 Implicit wanting (IW)

Table 5.21 displays the results of Bivariate Pearson's analysis between LFPQ IW preferences habitual intake for overweight and lean participants.

IW sweet bias and sugar intake (g) were inversely associated in lean participants but not overweight, although the overall moderation model was not significant (b = -.0031, 95% CI [-.0835, .0774], t = -.0759, p = .9397). IW sweet bias and sugar intake (%) were inversely associated, although the overall moderation model was not significant (b = .2496, 95% CI [-.3037, .8028], t = .8984, p = .3718). IW LFSA and sugar intake (g) were inversely associated in lean participants but not overweight, although the overall moderation model was not significant (b = -.0266, 95% CI [-.0841, .0309], t = -.9208, p = .7803). IW LFSA and sugar intake (%) were inversely associated in lean participants but not overweight, although the overall moderation model showed was not significant (b = -.3009, 95% CI [-.6962, .0944], t = -1.5163, p = .1336).

Table 5.21 Correlations between LFPQ IW preferences and habitual intake.

	Overweight (*n*=46)										Lean (*n*=30)									
	Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)		Sugar (g)		Sugar (%)		Fat (g)		Fat (%)		TEI (kcal)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Sweet bias	-.004	.980	.162	.283	-.167	.267	-.172	.252	-.126	.403	**-.151**	**.395**	**-.243**	**.165**	-.032	.855	-.129	.467	.023	.896
Fat bias	-.003	.985	-.055	.718	.052	.734	.001	.993	.046	.759	-.227	.196	-.263	.133	-.091	.607	-.155	.380	-.058	.744
HFSW	.068	.655	.151	.361	-.009	.952	-.088	.562	-.003	.984	-.033	.852	-.092	.604	.001	.997	-.150	.398	.069	.700
LFSW	-.085	.576	.070	.644	-.244	.103	-.160	.287	-.189	.209	-.176	318	-.246	.161	-.046	.797	-.028	.874	-.037	.836
HFSA	-.081	.591	-.230	.124	.062	.682	.103	.497	.050	.741	-.176	.318	-.246	.161	-.046	.797	-.028	.874	-.037	.836
LFSA	-.030	.844	-.088	.560	.091	.549	.120	.429	.054	.723	**-.235**	**.182**	**-.205**	**.245**	-.112	.530	-.003	.984	-.155	.381

Note: Data are Pearson's *r* (p-value). Abbreviations. LFPQ = Leeds Food Preference Questionnaire. IW = implicit wanting. HFSW = high fat sweet. LFSW = low fat sweet. HFSA = high fat savoury. LFSA = low fat savoury.

5.7.4 Summary

Hypotheses;

1. EL sweet bias was positively associated with sweet food intake in overweight participants, and negatively associated with intake of savoury food in lean participants. BMI moderated EL sweet bias and savoury food intake with effects present at lower but not higher BMI.
2. EL sweet bias was associated with lower ‘savoury pleasantness’ in lean participants but not overweight, which was not moderated by BMI.
2. There was no association between EW taste preferences and test meal palatability in either overweight or lean participants.
2. Differences in the associations between IW taste preferences and test meal palatability ratings in overweight and lean participants were not moderated by BMI.
3. Differences in the associations between EL, EW and IW taste preferences and habitual dietary intake between overweight and lean participants were not moderated by BMI.

Additional findings

- EL HFSW was positively associated with savoury food intake in overweight participants, BMI moderated this association at low and mean levels of BMI but not at higher.
- EL LFSW was inversely associated with savoury food intake in lean participants, BMI moderated this association at lower but not higher BMI.

- EL HFSW and EL LFSW were positively associated with TEI in overweight participants. Both associations were moderated at higher but not lower BMI.

Differences in the associations between EW or IW taste preferences and *ad libitum* meal intake in overweight and lean participants were

5.8 Discussion

Individuals with overweight and lean participants displayed several differences in the association between sweet taste preferences and eating behaviour variables. Specifically, EL taste preferences were associated with an elevated intake of similar tasting foods in overweight participants, whereas lean participants demonstrated reduced intake of dissimilar foods – which was moderated by BMI. In lean participants EW and IW sweet bias scores were associated with a lower intake of a savoury food item in the *ad libitum* test meal, with no associations present in overweight participants, although BMI was not a significant moderator in these models. EL sweet bias was associated with a lower palatability rating of a savoury food in lean participants but not overweight, which was moderated by BMI. Finally, differences between overweight and lean participants in the associations between sweet taste preferences and habitual intake were not moderated by BMI.

It is important to note the limitations associated with numerous correlational analyses, the more inferences that are made the more likely that there will be an erroneous inference made and the likelihood of a type-I error increases largely (Curtin & Schulz, 1998).

5.8.1 Taste preference and *ad libitum* test meal intake

Overweight and lean participants displayed different associations between taste preferences and *ad libitum* intake of a test meal with sweet and savoury components. Differences in relationships with EL sweet bias were noted, with overweight participants displaying positive associations with sweet food intake and lean participants displaying negative associations with savoury food intake. The inverse association present in lean participants was moderated by BMI at mean and low levels, and is a finding that does not appear to have been reported previously. However, a so-called ‘transfer effect’ of preference from savoury to sweet tasting foods (but less pronounced transfer from sweet to savoury) in the context of sensory specific satiety has been demonstrated (Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010). In a study which provided healthy weight participants (mean BMI = 21.7kg/m^2) with a sweet or savoury preload prior to *ad libitum* consumption of sweet or savoury snacks, the authors showed the intake of sweet snacks following the savoury preload was higher (Griffioen-Roose et al., 2010). This effect of sensory specific satiety was not the same between sweet and savoury preloads, leading the authors to conclude that savoury taste has a stronger effect on subsequent food choice. However, the present findings show that sweet taste preference may have a stronger modulating effect on food intake than savoury. Moreover, this association was shown in the current thesis to be moderated by BMI and became statistically non-significant in individuals above a BMI of 25.75kg/m^2. According to the WHO this BMI value is termed ‘pre-obesity’ (WHO, 2019), thereby indicating that the association between taste preference and intake of a taste dissimilar food may not apply to individuals with overweight or obesity, suggesting that obesity may weaken the association between sweet taste preference and food intake. This has been displayed within the present data set as lean individuals displayed an inverse association between sweet taste preference and intake of a savoury food in a single test meal, as would be anticipated. However, this was not the case for individuals with overweight, leading to the conclusion that in lean individuals there exists a mechanism by which taste preferences protect against over consumption by inhibiting intake of less preferred foods – whereas in those with overweight or obesity this is diminised. Moreover, this is supported by Griffoen-Roose and colleague’s findings (2010) which used a sample with a mean BMI of 21.7kg/m^2. The present findings build on this by demonstrating lean and overweight differences.

Both EL HFSW and LFSW preferences and TEI were positively associated in overweight participants, but not lean, and these associations were moderated by BMI. This leads to the conclusion that regardless of fat content, an elevated sweet taste preference in overweight individuals is associated with an elevated energy intake, possibly contributing to overconsumption.

It has previously been suggested that implicit processes are more influential in the determination of intake than explicit process in overweight individuals (Mela, 2006). Similarly, it has been suggested that implicit processes are also of high importance in the determination of food consumption in lean individuals (Berridge, 1996). Within the current study, differences were noted between the groups in the associations between IW taste preferences and intake, with lean individuals displaying a positive association between IW LFSW and yoghurt intake, and a negative association between IW LFSW and risotto intake – associations absent in the overweight participants. This finding supports the claims of Berridge (1996) and refutes those made by Mela (2006). However, the moderation analysis revealed that BMI did not moderate these associations, therefore no firm conclusion about the role of BMI can be drawn and further work is necessary. In addition, the positive association between LFSW and yoghurt intake (a LFSW food) supports previous evidence demonstrating that taste preferences are important markers of habitual dietary intake (Lampure, 2016; 2019; Chao et al., 2014; Kaminski, Henderson, & Drewnowski, 2000).

The present findings revealed that BMI moderated the associations between sweet taste preferences and eating behaviour variables, but only when explicit liking was considered as a measure of sweet taste preferences. Differences between overweight and lean participants in these associations for either EW or IW were either not present or not moderated by BMI. Moreover, very few studies have examined the associations between taste preferences and intake of dissimilar tasting foods, therefore the inverse associations between sweet taste preference and savoury food intake in lean individuals (and the absence of this association in overweight) have not been reported in the literature. It is therefore challenging to speculate as to why these differences in associations are present, but altered taste sensitivity with higher levels of BMI and its function as a driver of food intake could be an interesting mechanism requiring more sensitive methodologies than were available in the present study.

5.8.2 Taste preference and test meal palatability ratings

Overweight participants displayed a positive association between EL HFSW and ‘savoury pleasantness’ which was moderated by BMI up to a value of 30.8kg/m^2. This is an unexpected finding, as the savoury food item was also relatively low in fat, thereby representing the opposite dimensions of HFSW, it would seem counterintuitive that a HFSW preference be positively associated with the pleasantness of LFSA food. In lean participants inverse associations between EL sweet bias and ‘savoury pleasantness’ and ‘liking for savoury taste’ were displayed. This in contrast to the overweight sample, is a more expected finding, suggesting that with an elevated sweet taste preference, the subjective palatability of savoury foods declines, although only in lean individuals. Similar to the associations between taste preference and *ad libitum* intake, this suggests that liking for sweet foods is inversely related to the perceived palatability of dissimilar tastes, in this instance the savoury taste of risotto. The unexpected finding in individuals with overweight may be spurious and probably do not warrant further speculation.

In addition to this, in both overweight and lean participants there were no associations present between EW taste preferences and palatability ratings. This supports the idea that the construct of ‘liking’ is more often associated with palatability, whereas wanting is more usually associated with motivation and food choice (Finlayson, King, & Blundell, 2007) (Berridge, 1996).

Similarly, in overweight participants there were no associations present between IW taste preferences and test meal palatability ratings. However, in lean participants there was a positive association between IW LFSA and ‘liking for a savoury taste’. Although no association was found in individuals with overweight, there was no moderation by BMI.

5.8.3 Taste preference and habitual intake

Overweight participants did not display any associations between EL, EW or IW sweet bias or fat bias scores and habitual intake of sugar or fat. Contrary to previous work (Lampure, 2016; 2019; Chao et al., 2014; Drewnowski et al., 1999) this would suggest taste preferences in overweight individuals are not associated with habitual intake patterns. However, as previously stated there was a degree of under-reporting within the present study and so caution should be taken when drawing conclusions. However, as there was no between group differences in the extent of under-reporting, the change of a false-negative finding being drawn is reduced.

Moreover, in lean individuals EW and IW sweet bias scores were inversely associated with sugar intake (g) and (%). A study examining the association between self-reported eating behaviour and BMI noted that responsiveness to food reward predicted BMI, with impulsiveness moderating this relationship (Price, Higgs, & Lee, 2015). With this in mind it may be that psychological trait variables are better able to explain these associations between taste preferences and eating behaviour than BMI. Moreover, evidence has shown when using solutions of sucrose in water as a measure of sweet liking, a positive association exists between sweet preference and preferences for sweet desserts in healthy weight women (mean BMI = 23.2 kg/m^2) (Drewnowski, Henderson, Levine, & Hann, 1999). Furthermore, authors also identified that taste preferences were associated with intake in the current diet, although sugar was not measured as an outcome. Taken together these findings suggest that liking may be more influential in the determination of food intake than wanting, supportive of previous claims to this effect (Cox et al., 2016), however within the present study it is shown to only occur in lean individuals.

Interestingly, inverse associations were observed between both EW and IW sweet bias and sugar intake (g) and (%) in lean participants, which is contrary to previous work. Evidence has shown when using solutions of dissolved sucrose in water as a measure of sweet liking, a positive association exists between sweet preference and preferences for sweet desserts in healthy weight women (mean BMI = 23.2 kg/m^2) (Drewnowski, Henderson, Levine, & Hann, 1999). Furthermore, Drewnowski and colleagues (1999) also identified that taste preferences were associated with intake in the current diet, however, sugar was not measured as an outcome. In addition, lean individuals displayed positive associations between EL and EW LFSA and sugar intake (g) and (%). This is an unexpected finding, however, Griffioen-Roose (2010) demonstrated that savoury taste modulates subsequent food choice, with a savoury preload increasing intake of sweet snacks. From this it can be concluded that explicit LFSA preferences are associated with a higher intake of sugar in lean individuals, it may seem counterintuitive that a preference for savoury food items would be associated with a higher intake of sugar.

However, the food diary methodology MyFood24 employed in the present study does not make the distinction between sweet and non-sweet/savoury sugars or carbohydrates. Sugar as measured by MyFood24 is not synonymous with sweet foods and is in a number of savoury foods also (e.g. potatoes). This positive association therefore warrants further investigation into the sources of foods or food categories, as work that has previously done this has shown important differences in the sources of sugar in lean and overweight participants, with elevated intake of sugar from nutrient-dense sources (e.g. fruits, vegetables, grains) associated with a lower obesity risk (Lampure, 2016).

The associations observed in the present study warrant further investigation. Specifically, the sources of foods demand consideration as examination of macronutrient intakes has been revealed here to provide an incomplete picture. Furthermore, BMI can only be considered as an inconsistent moderator of the associations between taste preferences and eating behaviour variables. Further investigation considering also taste sensitivity in BMI, with more sensitive methodologies for assessing taste sensitivity would be of interest.

5.8.4 Conclusion

From the present evidence it can be concluded that overweight and lean women differ in the associations between taste preferences and eating behaviour variables. Specifically, lean individuals display an elevated sweet taste preference which is associated with a lower intake of savoury food items in an *ad libitum* test meal and is also associated with lower palatability ratings to a savoury food item and a lower habitual intake of sugar. In overweight participants, a higher sweet preference is associated with a higher intake of a sweet food item, and there appears to be no association present between sweet taste preference and test meal palatability ratings and habitual intake in overweight individuals.

It can be concluded from these findings that although differences are present in the associations between taste preferences and eating behaviour variables between overweight and lean participants, BMI appears to moderate the association between EL sweet taste preferences and *ad libitum* intake, with no consistent role for BMI in the association between EW and IW and other eating behaviour variables. The reason for the moderation only occurring for EL and not EW and IW remains unclear, however it can be speculated that this reflects a stronger association between EL and BMI. It is possible to like a stimulus in the absence of wanting it and the two components of food reward can be dissociated (Hobbs, Remington, & Glautier, 2005). It is possible that the associations between liking and wanting with BMI are different, with the present data supporting the idea that BMI exerts a greater influence over liking than wanting.

Chapter 6 General Discussion

6.1 Overview of thesis

The present thesis examined the influence of BMI on sweet taste preference in women. The work was inspired by the conceptualisation of sweet taste preference according to liking versus wanting sub-components of food reward and their relationship to biopsychological correlates of eating behaviour including actual test meal intake when faced with savoury and sweet food options, palatability of such items and habitual dietary intake of sugar, fat and other macronutrients. Liking and wanting for sweet and savoury foods were measured by a behavioural task (LFPQ) which was developed to provide assessment of explicit liking and both explicit and implicit wanting (Finlayson, King, & Blundell, 2007). The protocol employed was highly standardised and specific in its design to examine differences in eating behaviour between overweight and lean women. The approach taken in the current thesis to assess sweet taste preference differences was novel as to date no work has previously utilised the LFPQ in this manner.

The overarching research question in the present thesis was to examine the role of BMI in sweet taste preferences in overweight and lean women. This was subsequently broken down into three separate aims and corresponding research questions. Firstly, to examine the relationship between sweet taste preference and eating behaviours. Secondly, to test for differences in sweet taste preferences between overweight and lean women. Lastly, to examine the role of BMI as a moderator of the relationship between sweet taste preference and eating behaviour. In a cross-sectional, between-subjects study design, 40 lean women were recruited, and matched in age and physical activity level to an existing sample of 46 women with overweight.

6.1.1 Associations between taste preferences and eating behaviour variables

The first research question (Chapter 3) aimed to investigate the associations between taste preferences as measured by the LFPQ and intake of sweet, savoury and total food intake in an *ad libitum* meal, subjective palatability ratings to a sweet and savoury foods as well as habitual dietary intake of sugar, fat and TEI.

Findings showed sweet taste preference was positively associated with sweet food intake in an *ad libitum* meal. These results corroborate previous evidence demonstrating a link between taste preferences and food intake (Kaminski, Henderson, & Drewnowski, 2000). Interestingly, sweet taste preference also displayed negative associations with savoury intake. Due to the method used to calculate sweet bias scores (savoury scores subtracted from sweet scores), this finding reflects sweet preference relative to savoury preference. Therefore, it is possible for sweet bias score to be a negative value, indicating a greater liking for savoury relative to sweet food. The inverse association may therefore be indicative of a greater liking for savoury foods leading to consumption of the savoury food in the test meal.

An EL LFSA preference was also associated with elevated palatability ratings in response to a savoury food item. Additionally, positive associations were present between habitual dietary fat intake and liking for different sweet/fat combinations – specifically, HFSW, LFSW and HFSA. It was concluded from these findings that sweet taste preferences do correlate with eating behaviour variables, however it is still necessary to establish the direction of this effect as previous work has shown that habitual consumption of a food can increase the subsequent future preference (Appleton & Blundell, 2007; Costell et al., 2010). These positive associations may therefore represent a heightened taste preference being driven by an elevated habitual intake of specific foods, or alternatively elevated intake being driven by a heightened preference.

6.1.2 Differences in sweet taste preferences between overweight and lean women

Previous research has proposed there may be differences in sweet taste preferences between overweight and lean women, specifically as women with overweight and obesity tend to report an elevated preference for combinations of sweet and fat (Deglaire et al., 2015; Drewnowski & Greenwood, 1983; Drewnowski, Henderson, Levine, & Hann, 1999; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992).

Chapter 4 assessed differences in several determinants of sweet taste preference between overweight and lean women. These included, LFPQ scores, *ad libitum* test meal intake, test meal palatability ratings and habitual dietary intake. Contrary to predictions, there were no significant differences between overweight and lean participant's sweet or fat taste preferences. Examination of different specific sweet/fat combinations similarly did not reveal any significant differences according to BMI-status. Examination of the group as a whole revealed a higher preference for savoury over sweet foods and high fat over low fat foods. The use of BMI as a dichotomous variable may have been insufficient at detecting differences in sweet taste preference which are assumed to be directly related to body fat levels (Drewnowski, 1997). However, using WHO BMI cut-off criteria provided a clear categorical distinction between groups, as well as allowing direct comparisons with previous studies which have also used this approach.

Contrary to expectations, participants did not differ in their *ad libitum* test meal intake. The foods provided in the *ad libitum* meal were carefully chosen to be as to be representative of foods typically consumed during a meal. Moreover, all participants during the recruitment process were screened to ensure that test meal foods were well liked. This provides a greater element of confidence when concluding that overweight and lean women do not differ in their *ad libitum* intake of sweet and savoury foods at a particular meal. However, it has previously been shown that individuals with obesity ingest a higher amount of calories from snacking relative to lean individuals (Bertéus Forslund, Torgerson, Sjöström, & Lindroos, 2005). This suggests, with the results from the present study, that over consumption in individuals with obesity may not occur in a single meal, but in smaller, cumulative amounts throughout the day.

However, participants did not differ in their habitual dietary intake either as measured by Myfood24. It is possible that this lack of difference was due to mis-reporting within the data, however this is unlikely as the extent of under-reporting was similar in both groups. It is also possible that this may be an indication of differences between groups' physical activity levels, however this is unlikely due to a strict eligibility criteria and screening process (i.e. engaging in physical activity a maximum of 3 times a week).

Finally, differences were observed in the palatability responses to a sweet and savoury food; overweight participants displayed higher palatability ratings to a savoury food item than lean participants, supportive of previous research (van Langeveld et al., 2018) showing overweight women display an elevated preference for savoury foods relative to lean counterparts, as inferred from the percentage energy consumed within the diet from these foods.

From these findings it is concluded that sweet taste preferences, as defined by EL, EW and IW, did not differ between overweight and lean women, this null outcome is consistent with findings regarding *ad libitum* test meal intake of a sweet, savoury or total food, and habitual dietary intake, which also did not differ between groups in this study.

6.1.3 Moderating effect of BMI on the associations between sweet taste preference and eating behaviour variables.

In the scientific literature there is evidence to demonstrate a difference in sweet taste preferences between overweight and lean women when using BMI to distinguish participants; although the findings from Chapter 4 suggest that differences may be more limited than thought elsewhere and dependent on the sample examined. There is also evidence to suggest that taste preferences are related to eating behaviours. In this manner, BMI was hypothesised to moderate the relationship between sweet taste preference and eating behaviour variables as shown in Figure 6.1.

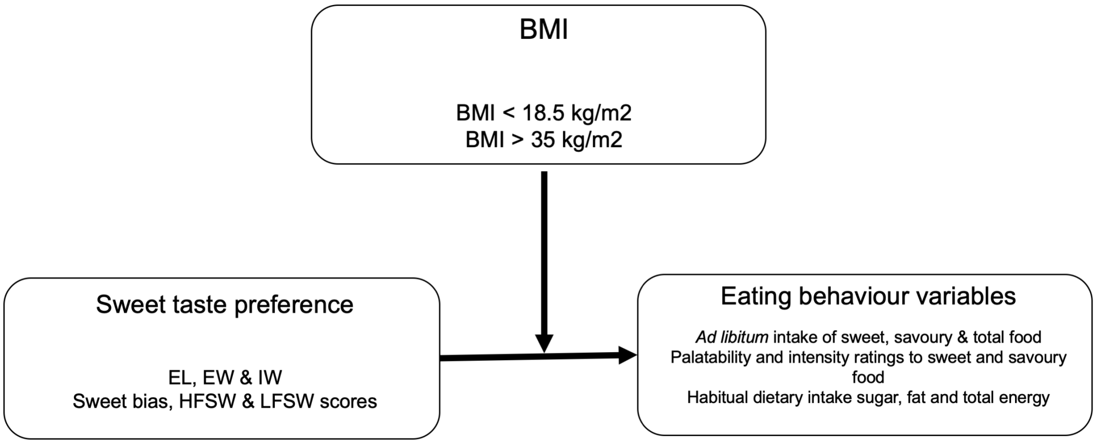

Figure 6.1 Proposed moderation model.

Therefore, in chapter 5, associations were examined between sweet taste preference as measured by the LFPQ, and *ad libitum* intake of a sweet, savoury and total food, test meal palatability ratings and habitual dietary intake of sugar, fat and TEI. BMI was used in two ways; firstly as a dichotomous variable with participants characterised as either overweight or lean, and secondly, as a continuous moderator variable. The benefit of using BMI as a continuous variable within the moderation model is that it enabled post-hoc investigation using the Johnson-Neyman technique to identify the point on the continuum at which the moderation becomes significant.

Several differences were observed between overweight and lean participants in the associations between taste preferences and eating behaviour variables. Overweight participants displayed positive associations between both EL and EW sweet taste preference and intake of a sweet food in an *ad libitum* meal, whereas lean participants exhibited a negative association between sweet taste preference and intake of a savoury food. The positive association observed in overweight participants supports previous evidence that has shown associations between taste preference measures and subsequent intake when using FFQs (Kaminski, Henderson, & Drewnowski, 2000). However, the inverse association observed in lean participants is an unanticipated finding and warrants further investigation. This may indicate a self-regulatory mechanism within lean individuals that is not present in overweight, with a sweet taste preference associated with choice/avoidance of savoury rather than driving intake of sweet food. Similarly, lean individuals displayed negative associations between EL sweet taste preferences and palatability ratings in response to a savoury food item. It could be proposed from this that sweet preferences in women with overweight or obesity do not diminish the palatability of savoury food, thus permitting greater intake of these foods compared to lean women. On the other hand, it may be due to the calculation of sweet bias scores (savoury scores subtracted from sweet scores). Because of this sweet bias scores represent a sweet preference relative to savoury, and negative sweet bias score reflects a savoury preference. Therefore, the inverse association may reflect a greater liking of savoury foods relative to sweet foods and may indicate a positive association between savoury taste preference and intake of a savoury food.

Finally, overweight participants did not display any associations between EL, EW or IW sweet taste preferences and habitual dietary intake. The lack of associations in overweight participants may be explained by these women providing data at the beginning of a weight-loss trial. These individuals therefore represent a motivated sample actively seeking to lose body fat, which may have altered their habitual intake patterns (actual or reported), particularly given evidence has shown a weight-loss trial increases the severity of misreporting (Johnson et al., 2005). Additionally, under-reporting may have been problematic for foods particularly relevant to the current research questions. Foods with a negative health image such as those that are HFSW (e.g. cakes, sweet and confectionary) are more likely to be under-reported than foods with a positive health image (Macdiarmid & Blundell, 1998). As outlined above, there were no differences between groups' in the extent of under-reporting and physical activity levels were carefully considered during the recruitment process. Therefore, the under-reporting is possibly a consequence of elevated self-monitoring which would dampen the suggested positive association in the overweight sample, and in the lean sample lead to a negative association.

Moderation analysis revealed that the differences in associations between sweet taste preference and *ad libitum* intake were moderated by BMI only for EL. Similarly, overweight and lean participants displayed different associations between EL sweet taste preferences and 'savoury pleasantness' ratings, which were also moderated by BMI. Finally, associations between taste preferences and habitual intake were not moderated by BMI. These findings suggest that the extent to which BMI moderates the associations between sweet taste preference (EL but not W) and eating behaviour variables is therefore modest, whether this applies to other markers of adiposity or body composition remains to be elucidated. Future work should consider more precise measures of body composition or adiposity given evidence which has implemented FM as key in these differences (Drewnowski, 1997; Fernandez-Garcia et al., 2017; Zhang et al., 1994)

6.2 Contribution of liking and wanting to sweet taste preferences

Previous work has suggested that individuals with overweight and obesity present with a higher liking for foods relative to lean individuals (Bartoshuk et al., 2006). In addition to this, when using skinfold measurements to categorise women as either overweight or lean it was found that a higher body fatness was associated with a higher liking for stronger sucrose concentrations (Ettinger, Duizer & Caldwell, 2012). This displays an association between body fat levels and liking for sweet with differences between overweight and lean individuals present. However, within the present thesis these differences were not replicated. No between group differences were noted for sweet bias liking scores within the LFPQ or subjective palatability ratings in response to a sweet food item. This may be due to a potential methodological limitation as it is possible to argue that any assessment of food liking without ingestion of a real food stimulus will be confounded to an extent by wanting. EL may be overestimated in the absence of physical experience, with a food wanted (explicitly or implicitly) more than it is liked. Equally, previous work has provided participants with a number of stimuli varying in sweet concentration, rather than one standardised sweet stimulus as in the present study in the test meal (Havermans, 2011). Varying concentrations enables identification of different taste thresholds between participants which appear to be influential in the determination of liking (Jayasinghe et al., 2017), and subsequently provision of one standardised stimulus may not have been sufficient at detecting these differences.

Overweight individuals are believed to possess an elevated preference towards HFSW foods (Drewnowski, 1997; Drewnowski et al., 1992). Bartoshuk and colleagues (2006) went so far as to claim that obese individuals live in different orosensory worlds characterised by reduced sweet perception which intensifies fat sensations. However, within the present data there were no differences between overweight and lean women’s liking for HFSW or LFSW foods. This was an unanticipated finding, although previous work utilising a sample of only overweight individuals (Drewnowski et al., 1992) and therefore the preferences relative to lean individuals cannot be stated. Within the present thesis it is shown that relative to lean counterparts, the preference for HFSW is not elevated in women with overweight or obesity as no differences were noted between groups.

It has previously been noted that EL and IW are capable of predicting energy intake (French, Mitchell, Finlayson, Blundell, & Jeffery, 2014) recorded by dietary recall interviews. This finding was not replicated within the current thesis. It has been calculated that for accurate estimation of habitual dietary patterns, a minimum of 6 days is necessary at a group level (Basiotis, Welsh, Cronin, Kelsay, & Mertz, 1987). A strength of the present study is that participants provided 7 days of 24-hour food diaries and so provides confidence in the extent to which it is representative of habitual intake patterns. These differences in the collection of habitual dietary intake may explain the differences in findings.

It has also been suggested that overweight individuals display a higher level of wanting towards foods than lean individuals (Saelens & Epstein, 1996) although this was shown via an increased willingness to work for food relative to sedentary activities. However, a study by Dalton observed greater intake of HFSW foods and an elevated wanting for these foods in obese individuals only when also sub-categorised as at risk of binge eating (Dalton, Blundell & Finlayson, 2013). Binge eating is known to be positively associated with body weight (Telch, Agras & Rossiter, 1988; Micali, Field, Teasure & Evans, 2015) and therefore it may be that an increased wanting observed in overweight participants occurs due to the higher incidence of binge eating in overweight individuals. Future work may wish to consider psychobiological traits associated with body weight in the determination of taste preferences and the associations with eating behaviours – particularly considering BMI was only shown to be a modest moderator.

6.3 Strengths and limitations

The study protocol was carefully designed to measure a range of variables associated with taste preferences and eating behaviours, with careful consideration given to potential limitations. The age matching of participants during recruitment was successful, thereby negating the potential effects of age related differences in sweet taste preferences between overweight and lean groups (Desor & Beauchamp, 1987; Yoshinaka et al., 2016). In addition, all participants attended a screening visit prior to their assessment day and were excluded if the study foods were disliked. This enabled participants to exclude images of food within the LFPQ that were disliked and would not be freely chosen, allowing researchers to include appropriate images. This thereby served to improve the internal validity and accuracy of the findings of the LFPQ.

In the present study, visual analogue scales were used in the measurement of subjective palatability ratings in response to a sweet and savoury food. All participants were provided with the same training for completion of the VAS, and so this is unlikely to explain the lack of differences between BMI groups in Chapter 4. Examination of the reproducibility and validity of VAS has been shown to be reliable in studies utilising a single meal (Flint, Raben, Blundell, & Astrup, 2000) and although their use has been most extensively validated for sensations of appetite such as hunger, their use in sensory and hedonic research although common, is less well validated.

The use of VASs within the present was given careful consideration as despite being consistently used within appetite research there is work suggesting that they are not a sufficient measure for determining between group differences, particularly when groups are differentiated on the basis of body weight (Pepino & Mennella, 2012). It has been postulated that anchors on a VAS may be viewed differently between groups, particularly when the group's sensitivity to what is being measured differs (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006). To illustrate this, in a study which compared pain intensities, men and women were provided with a VAS anchored by 'no pain' and 'most intense pain ever experienced'. For women, the label 'most intense pain ever experienced' denotes a much greater pain than it does for men which was reflected in the results (Dionne, Bartoshuk, Mogil, & Witter, 2005). A general labelled magnitude scale (gLMS) has been proposed as a more sensitive measure. Spaces between labels on the scale are adjusted to provide ratio properties (i.e. a 'sweetness intensity' rating of '50' would be perceived twice as intense as a rating of '25') and as a consequence it is a more sensitive measure to the differences in subjective ratings across different groups (Bartoshuk et al., 2006). However, during the screening session all participants were trained on the use of VASs by a qualified experimenter which is believed to negate these issues.

Assessment of energy and nutrient intake in a laboratory setting provides a high level of experimental control. This method has numerous benefits as it facilitates the implementation of precise experimental manipulation of variables thereby supporting a high degree of precision. However, the artificial environment is also capable of constraining a participant's behaviour and so there is a careful balance to be struck between precision and naturalness (Blundell et al., 2009). It should be clearly stated that appetite assessment within the laboratory does not attempt to replicate feeding conditions within the participant's natural environment, rather it provides a platform to measure eating behaviour free from social chaos and confounding factors (Blundell et al., 2009). However, in the present protocol eating behaviour assessment was assessed via both *ad libitum* test meal and habitual dietary intake, thereby providing a picture of both single meal intake in a controlled environment, as well as free-living intake in a more natural setting.

The *ad libitum* food items were chosen due to their representation of typically consumed foods, were commercially available food items and were homogenous foods rather than typically portioned foods (e.g. sandwiches). This is a benefit of the protocol, increasing the validity of the results and conclusions drawn. For this reason, despite the meal being ingested in an artificial and unfamiliar environment it was as close to a typically consumed lunch meal as possible. Moreover, the two foods were closely matched for energy density and so differences in satiation that may have resulted due to consumption of different proportions of the savoury and sweet foods were minimised.

Retrospective methods of assessing dietary intake are flawed in their measurement of a participant's memory of past diet, rather than the diet itself (Krall, Dwyer, & Ann Coleman, 1988). As a consequence, validity is reliant on accurate and honest recall by participants. Moreover, in women the accuracy of self-reported dietary recall is negatively impacted by social desirability (Hebert, Clemow, Pbert, Ockene, & Ockene, 1995). In order to provide an estimation of the incidence of under-reporting the Goldberg cut-off was employed (Goldberg et al., 1991). The mean TEI/RMR within the present data set was 1.29; a figure lower than expected and indicative of under-reporting, as previous research has suggested a figure of 1.2 is indicative of being bed bound and motionless (Black, Coward, Cole & Prentice, 1996) and the WHO's value for 'light activity' is 1.55 (WHO, 1985). The under-reporting may be due to a bias whereby participants reduce intake whilst actively monitoring their intake (Lissner, 2002). However, as there were no differences between groups in the extent of under-reporting this is likely not a major issue within the present analyses, although any conclusions drawn should be taken with caution.

Although there are limitations to assessment of habitual dietary intake, MyFood24 has been specifically developed for use within research environments and has been demonstrated as suitable for use in UK adults. It is the first online 24-h dietary assessment tool for UK populations with a food composition database specifically designed for its use (Carter et al., 2015). In addition to this, data obtained via MyFood24 has been shown to be as reliable as that collected via interviews (Albar, Alwan, Evans, Greenwood, & Cade, 2016). Therefore, despite there being a deal of under-reporting within the current sample, MyFood24 is believed to provide a valuable insight into the habitual dietary intake of participants. Furthermore, providing there is an acknowledgement of the limitations of the assessment of haitaul dietary intake, it has been concluded to provide valuable information regarding habitual dietary patterns that can be used to inform research (Subar et al., 2015).

A final limitation is that BMI was examined as the potential moderator of the associations between taste preferences and eating behaviour variables. Future work may wish to consider a more direct measure of adiposity such as %BF; however as previously outlined this would not enable comparison with studies that have used BMI as a method of categorising participants. If body composition is shown in future work to be a poor moderator of these associations, psychological traits such as eating restraint or craving control, may additionally be explored as potential moderators due to their higher incidence in overweight and obese individuals (Chao, Grilo, White, & Sinha, 2014; Snoek, van Strien, Janssens & Engels, 2008; White et al., 2002).

6.4 Future work

As previously discussed in Chapter 3, the *ad libitum* test meal consisted of sweet and savoury food options, this is not necessarily problematic as sweet and savoury tastes account for approximately 90% of all foods eaten (Mattes, 1985). However, both were also relatively low in fat. This is limiting as it does not allow the expression of a high fat taste preference to be examined within the test meal. Future work would benefit from the inclusion of different sweet/fat combinations that would be typically overconsumed, such as cake, cookies or donuts as informed by previous research (Drewnowski et al., 1992), facilitating a greater understanding of the contribution of sweet taste preference to potential excess energy intake. In a protocol that utilises the LFPQ as an assessment of taste preferences this would be particularly beneficial, as taste preferences for different sweet/fat combinations could be assessed in relation to actual intake of foods representative of these different combinations. This would be particularly beneficial in testing previous assumptions that food preference checklists – an indication of taste preference – are reflective of real life food consumption (Meiselman, 1992). Furthermore, the food items selected in the present study did not represent foods that would be typically overconsumed; therefore, despite liking the food items participants will have been unlikely to overconsume them.

The foods images included in the LFPQ can be seen in Table 2.4 and although the foods were predominantly high (>40% energy) or low (<20% energy) in fat content and contrasted in taste (either sweet or savoury), the difference in taste cannot at this time be quantified. The sugar content and perceived sweetness of the LFPQ images remains unknown and participants are required to imagine the taste elicited by these foods as well as how strong this taste would likely be. Future work may wish to consider quantifying not only the fat content but also the sugar content of the LFPQ food images to provide a characterisation of high fat high sugar rather than simply high fat sweet etc.

Furthermore, appetite for something sweet and savoury is known to vary as a function of time, with savoury preferences more in line with traditional mealtimes and hunger fluctuations whereas sweet preferences are more prominent and consistent throughout the day (de Graaf, Jas, Van der Kooy & Leenen, 1993). For this reason, it may be that in an *ad libitum* lunch meal consisting of a sweet and savoury food items, differences in sweet and savoury taste preferences will not be accurately identified. In a Dutch sample it was observed that savoury intake was higher during meal times and sweet intake was higher during snacking events (van Langeveld et al., 2018). For this reason, future work may wish to consider the inclusion of not only an *ad libitum* test meal but also the inclusion of *ad libitum* snacking opportunities throughout an assessment day.

6.5 Proposed theoretical model

From the available evidence a cyclical process of sweet taste preference and BMI can be proposed. Taste preferences and past food intake are able to influence short-term intake, this over time develops into habitual eating behaviours, which then if overconsumed influences body weight which in turn impacts taste preferences – seen in Figure 6.2. Within the present thesis it has been demonstrated that BMI appears to influence the strength of a limited number of these associations, however, this cyclical process implies the existence of more complex, bi-directional relationship which could not be investigated in the present cross-sectional study design. To illustrate this, evidence demonstrates that it is possible to predict future weight gain via sweet taste preferences, highlighting a direction present in the associations between taste preference and eating behaviour not considered within the present thesis. In a sample of Pima Indians, weight gain at 5-year follow up was associated with a heightened hedonic response to sweet and fat stimuli at baseline (Salbe, DelParigi, Pratley, Drewnowski, & Tataranni, 2004). Similarly, in a Japanese sample, individuals reporting a sweet taste preference via FFQs experienced a significantly greater weight increase at 10-year follow up (Matsushita et al., 2009). Future work may wish to employ a longitudinal design in order to identify potential influences from taste preferences exerted on BMI and demonstrate the bi-directionality of these associations.

Palatability is an influential aspect in guiding our food choices and eating behaviours, the reward elicited by palatable foods is greater than that of bland foods, and the sensitivity to this reward may drive overeating (Appelhans et al., 2011). Differences in perceived palatability are reasoned to stem from differences in taste sensitivity associated with varying BMIs. Review of previous literature has identified that with increasing body fatness, taste sensitivity tends to become sub-optimal (Altun et al., 2016; Etinnger, Duizer & Caldwell, 2012). Additionally, it has been demonstrated that a substantial loss of body fat results in improvements to taste sensitivity (Altun et al., 2016). Given the loss of taste function that is associated with increasing levels of body fat, it is reasonable to hypothesis that differences in the associations between taste preferences and eating behaviours – as shown in chapter 5 - stem from differences in perceived palatability that are caused by variations in BMI.

Within the present study, subjective ‘intensity’ ratings were provided in response to standardised sweet and savoury food items as an indication of taste sensitivity. However, no differences were noted between overweight and lean participants. This may have resulted from an over-simplification in the testing of taste thresholds, as most commonly assessment occurs via provision of solutions or taste strips of varying intensities (Chamoun et al., 2019). However, there is evidence demonstrating that increased levels of adiposity within the body are associated with a reduced taste sensitivity (Altun et al., 2016; Berthoud & Zheng, 2012) and measures of sensitivity are inversely associated with intake (Tan & Tucker, 2019). This supports the proposition of a cyclical process, whereby body weight becomes elevated and taste sensitivity diminishes which also blunts the hedonic reward from foods (Berthoud & Zheng, 2012), it may be speculated that this causes an increased intake or stronger concentrations in order to receive the anticipated hedonic reward. Future work may wish to expand on the moderation model put forward within the present thesis and examine whether distorted taste thresholds mediate the influence of BMI on the association between sweet taste preference and eating behaviour.

Although within the present thesis it was shown that BMI moderates the associations between taste preferences and eating behaviour, the proposed mechanism of this change is differences in subjective palatability.

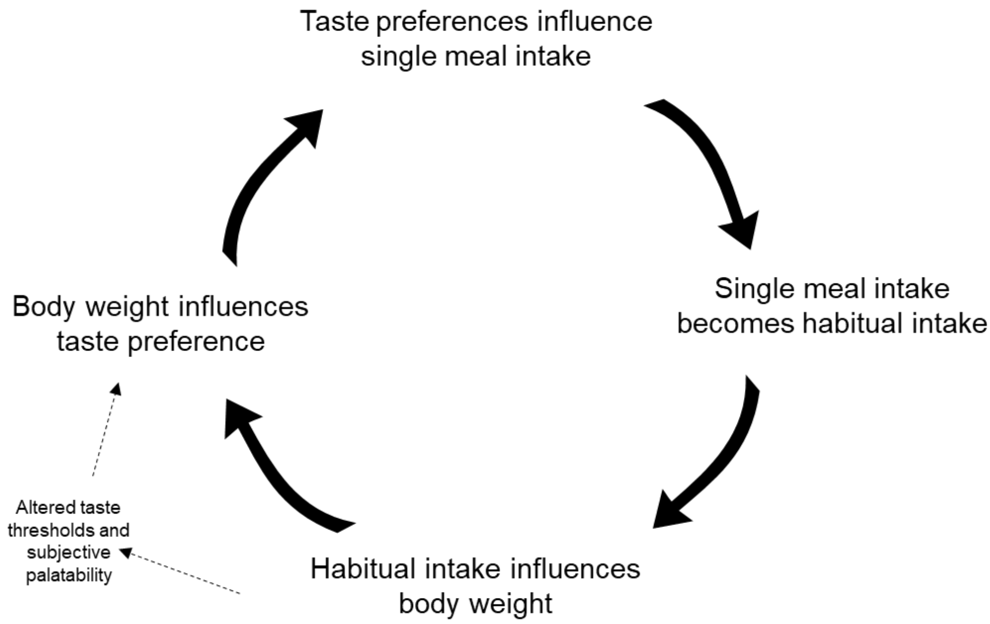

Figure 6.2 Cyclical process whereby taste preferences influence food intake and subsequent body weight.

6.6 Conclusion

From the present study it would appear that taste preferences, expressed in the liking of sweet compared to savoury food, are associated with eating behaviour within a single meal and habitual dietary intake, however this is not as clear or consistent as previous research has indicated (Bobroff & Kissileff, 1986; Deliens, Clarys, De Bourdeaudhuij, & Deforche, 2014; Food Marketing Institute. Research Dept, & Opinion Research Corporation (US), 1996; Kaminski et al., 2000). Additionally, associations between wanting of sweet compared to savoury food, and eating behaviour variables are less evident.

Associations between sweet taste preference and intake of taste similar (sweet) foods and inverse associations with taste dissimilar (savoury) foods provide an uncertain picture and warrant further investigation with improved measures of taste sensitivity. Contrary to hypotheses, overweight and lean participant's sweet and sweet/fat combination taste preferences did not differ in this study. Liking and wanting for sweet foods were examined using the LFPQ, a behavioural task that has been used extensively within research (Andriessen et al., 2018; Buckland et al., 2018; Cameron, Goldfield, Finlayson, Blundell, & Doucet, 2014b). Several associations between taste preferences and eating behaviour variables were shown to differ between overweight and lean participants despite there being no absolute differences in means between the groups. BMI was subsequently found to moderate some associations between taste preference and eating behaviour but this was primarily for EL for sweet relative to savoury foods. Associations between EW or IW as indices of sweet taste preferences and associations with habitual dietary intake were inconsistent and BMI is therefore unlikely to play to a strong role.

It has been previously suggested that 'un-sweetening' the world's diet may be a possible solution to the current obesity epidemic (Yang et al., 2019), however, the current findings suggest that there is little difference between the intakes of participants with overweight or with a healthy weight. However, it appears that BMI is capable of influencing the associations between taste preferences and eating behaviour variables – specifically the association between explicit liking for sweet taste and total energy intake in a single meal. Women with overweight with an EL HFSW preference had a higher total energy intake in a single test meal, suggesting that it is not a sweet taste preference that contributes to excess intake, but rather a sweet and fat preference. Identification of this propensity to eat excess calories may assist in the development of targeted intervention techniques to assist in the reduction of energy intake in females with overweight and an elevated EL HFSW preference. Furthermore, this may provide justification for the development of reduced 'energy foods' which possess the hedonic sweet taste via high-intensity sweeteners, thereby enabling consumer enjoyment of products without the associated excess energy intake.

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Appendix 1 Participant screening questionnaire for overweight followed by lean samples.

Date _____ /_____ /_____

Name ……………………………………………………………………………………………

Contact phone number ……………………………………………………..……………

E-mail ………………………………………………………………………………….............

Date of Birth _____ / _____ /_____ **Age** ………………………………...

Measured height ………………..………….. **Measured weight** ………………………………………

Measured BMI ………………………………….

Lab use

How would you describe your employment?

Employed ☐
Retired ☐
Student ☐
Full-time homemaker ☐
Unemployed ☐
Unable to work ☐
Other ☐

If employed what job do you do? ……………………………………………………………
Does this entail shift work? Yes No

Do you smoke?
Yes ☐
No ☐
Given up ☐

How long ago?..................................

EXERCISE

Do you do regular exercise? Yes / No

What type of exercise do you do?
……

Have you changed the amount of exercise you do in the last 6 months?
Yes / No If yes please give details
………………………………………………………………………………...

DIET

Has your weight changed at all over the previous six months?

Yes / No If yes, please provide details such as how much weight was lost or gained.

………

…….

Do have any food intolerances/allergies or have a history of anaphylaxis to food?

Yes / No Details

………

…….

Are there any specific foods that you do not like and could not eat?

Yes / No Details

………

…….

Alcoho l	During the last 12 months, how often did you usually have any kind of drink containing alcohol? **By a drink we mean a unit**. Choose only one.  	Every day 5 to 6 times a week 3 to 4 times a week twice a week once a week 2 to 3 times a month once a month 3 to 11 times in the past year 1 or 2 times in the past year (IF RESPONDENT GIVES ANY OF THE ABOVE RESPONSES, GO TO QUESTION 2) I did not drink any alcohol in the past year, but I did drink in the past (GO TO QUESTION 1A) I never drank any alcohol in my life (GO TO QUESTION 1B)
1a	During your lifetime, what is the maximum number of drinks containing alcohol (units) that you drank within a 24-hour period? (asked here only of those who did not drink any alcohol during the past 12 months)	36 drinks or more 24 to 35 drinks 18 to 23 drinks 12 to 17 drinks 8 to 11 drinks 5 to 7 drinks 4 drinks 3 drinks 2 drinks 1 drink
1b	So you have never had a drink containing alcohol in your entire life. (asked only of those who say they never drank alcohol in their lives)	Yes, I never drank. (DONE WITH ALCOHOL QUESTIONS) No, I did drink (GO BACK TO QUESTION 1 AND REPEAT)

2	During the last 12 months, how many alcoholic drinks (units) did you have on a typical day when you drank alcohol?	25 or more drinks 19 to 24 drinks 16 to 18 drinks 12 to 15 drinks 9 to 11 drinks 7 to 8 drinks 5 to 6 drinks 3 to 4 drinks 2 drinks 1 drink
3	During the last 12 months, how often did you have 5 or more (males) or 4 or more (females) drinks (units) containing any kind of alcohol in within a two-hour period? [That would be the equivalent of at least 5 (4) cans or bottles of beer, 5 (4) five glasses of wine, 5 (4) drinks each containing one shot of liquor or spirits - to be provided by interviewer if asked.] Choose only one:	Every day 5 to 6 days a week 3 to 4 days a week two days a week one day a week 2 to 3 days a month one day a month 3 to 11 days in the past year 1 or 2 days in the past year

Are you currently dieting to lose or maintain weight?

Yes, I am currently dieting to lose weight. ☐
Yes, I am currently dieting to maintain my weight. ☐
No, I am not currently dieting. ☐

If you are currently dieting, are you following a specific programme or diet plan?

Yes / No Details
…………………………………………………………………………………………..
......

How often in your life have you attempted to lose weight?

- ❍ 1-2 times
- ❍ 3-5 times
- ❍ 6-10 times
- ❍ more than 10 times

PREGNANCY

Have you been pregnant in the last 6 months or planning to get pregnant? Yes/ No

Are you currently breast-feeding or have breast fed in the last 6 months? Yes / No

HEALTH

How would you rate your general health……………………………………………………………………………

Do you have any medical conditions? (e.g. heart condition, asthma, diabetes, hypothyroidism)

Yes / No   Details
………………………………………………………………………………………...
......

Do you take any prescribed medication?

Yes / No   If yes, please give
details………………………………………………………………………………………

……
…………………………

Have you had weight loss surgery? (e.g. gastric bypass, stomach stapling)

Yes / No   If yes please give details
………………………………...……………………………………………

……
…………………………

Have you experienced an eating disorder? (e.g. anorexia nervosa, bulimia nervosa, binge eating disorder)

Yes / No   If yes please give details
……………………………………………………………………………………...

………………………………………………………………………………………………………........
....

Are there any other health issues (e.g. medical, physical, mental health etc) that may have an effect on your participation in this research study?

Yes / No   If yes please give details
……………………………………………………………………………………...

……
…………………………

You may be required to eat the following foods during the study. Please rate the foods listed in the table below according to how much you LIKE or DISLIKE them.

	Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neutral	Like Slightly	Like Moderately	Like Very Much	Like Extremely
Muesli	❍	❍	❍	❍	❍	❍	❍	❍	❍
Raisins/Sultanas	❍	❍	❍	❍	❍	❍	❍	❍	❍
Honey yoghurt	❍	❍	❍	❍	❍	❍	❍	❍	❍
Apple	❍	❍	❍	❍	❍	❍	❍	❍	❍
Banana	❍	❍	❍	❍	❍	❍	❍	❍	❍
Orange	❍	❍	❍	❍	❍	❍	❍	❍	❍
Melon	❍	❍	❍	❍	❍	❍	❍	❍	❍
Pineapple	❍	❍	❍	❍	❍	❍	❍	❍	❍
Mango	❍	❍	❍	❍	❍	❍	❍	❍	❍
Carrot	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cherry tomato	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cucumber	❍	❍	❍	❍	❍	❍	❍	❍	❍
Lemon chicken risotto	❍	❍	❍	❍	❍	❍	❍	❍	❍
Vegetable lasagne	❍	❍	❍	❍	❍	❍	❍	❍	❍
Chicken curry	❍	❍	❍	❍	❍	❍	❍	❍	❍
Chicken chow mein	❍	❍	❍	❍	❍	❍	❍	❍	❍
Tomato & herb risotto	❍	❍	❍	❍	❍	❍	❍	❍	❍
Porridge	❍	❍	❍	❍	❍	❍	❍	❍	❍

Low-calorie chocolate mug cake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Scotch broth	❍	❍	❍	❍	❍	❍	❍	❍	❍
Vegetable broth	❍	❍	❍	❍	❍	❍	❍	❍	❍
Spaghetti bolognaise	❍	❍	❍	❍	❍	❍	❍	❍	❍
Three cheese pasta	❍	❍	❍	❍	❍	❍	❍	❍	❍
Shepard’s pies	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie banana shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie strawberry shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie chocolate shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie vanilla shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie peanut crunch bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie toffee chocolate bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie fudge nut bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Strawberry yoghurt	❍	❍	❍	❍	❍	❍	❍	❍	❍
Water	❍	❍	❍	❍	❍	❍	❍	❍	❍
Coffee	❍	❍	❍	❍	❍	❍	❍	❍	❍

Tea	❍	❍	❍	❍	❍	❍	❍	❍	❍

THANK YOU

The information you have provided in this form will be kept strictly confidential.

Would you like us to keep your details on file and contact you about any future studies that we have? **Yes / No**

Date _____ /_____ /_____

Name ………………………………………………………………………………………

Contact phone number …………………………………………………..……………

E-mail ………………………………………………………………………………….............

Date of Birth _____ / _____ /_____ **Age** …………………………………...

Measured height …………………..………… **Measured weight** ……………………………………….

Measured BMI ……………………………………

Lab use

How would you describe your employment?

Employed ☐ Unemployed ☐
Retired ☐ Unable to work ☐
Student ☐ Other ☐
Full-time homemaker ☐

If employed what job do you do? ………………………………………………………………
Does this entail shift work? Yes No

Do you smoke?
Yes ☐
No ☐
Given up ☐
How long ago?..................................

EXERCISE

Do you do regular exercise? Yes / No

What type of exercise do you do?
....

Have you changed the amount of exercise you do in the last 6 months?
Yes / No If yes please give details
…………………………………………………………………………………...

DIET

Has your weight changed at all over the previous six months?
Yes / No If yes, please provide details such as how much weight was lost or gained.

..……………………………………………………………………………………………………
…….

Do have any food intolerances/allergies or have a history of anaphylaxis to food?

Yes / No Details

……

…….

Are there any specific foods that you do not like and could not eat?

Yes / No Details

……

…….

Alcohol	During the last 12 months, how often did you usually have any kind of drink containing alcohol? **By a drink we mean a unit**. Choose only one.  	Every day 5 to 6 times a week 3 to 4 times a week twice a week once a week 2 to 3 times a month once a month 3 to 11 times in the past year 1 or 2 times in the past yea (IF RESPONDENT GIVES ANY OF THE ABOVE RESPONSES, GO TO QUESTION 2) I did not drink any alcohol in the past year, but I did drink in the past (GO TO QUESTION 1A) I never drank any alcohol in my life (GO TO QUESTION 1B)
1a	During your lifetime, what is the maximum number of drinks containing alcohol (units) that you drank within a 24-hour period? (asked here only of those who did not drink any alcohol during the past 12 months)	36 drinks or more 24 to 35 drinks 18 to 23 drinks 12 to 17 drinks 8 to 11 drinks 5 to 7 drinks 4 drinks 3 drinks 2 drinks 1 drink
1b	So you have never had a drink containing alcohol in your entire life. (asked only of those who say they never drank alcohol in their lives)	Yes, I never drank. (DONE WITH ALCOHOL QUESTIONS) No, I did drink (GO BACK TO QUESTION 1 AND REPEAT)
2	During the last 12 months, how many alcoholic drinks (units) did you have on a typical day when you drank alcohol?	25 or more drinks 19 to 24 drinks 16 to 18 drinks 12 to 15 drinks

		9 to 11 drinks 7 to 8 drinks 5 to 6 drinks 3 to 4 drinks 2 drinks 1 drink
3	During the last 12 months, how often did you have 5 or more (males) or 4 or more (females) drinks (units) containing any kind of alcohol in within a two-hour period? [That would be the equivalent of at least 5 (4) cans or bottles of beer, 5 (4) five glasses of wine, 5 (4) drinks each containing one shot of liquor or spirits - to be provided by interviewer if asked.] Choose only one:	Every day 5 to 6 days a week 3 to 4 days a week two days a week one day a week 2 to 3 days a month one day a month 3 to 11 days in the past year 1 or 2 days in the past year

Are you currently dieting to lose or maintain weight?

Yes, I am currently dieting to lose weight. ☐
Yes, I am currently dieting to maintain my weight. ☐
No, I am not currently dieting. ☐

If you are currently dieting, are you following a specific programme or diet plan?

Yes / No Details
…………………………………………………………………………………………......................................
......

How often in your life have you attempted to lose weight?

- ❍ 1-2 times
- ❍ 3-5 times
- ❍ 6-10 times
- ❍ more than 10 times

PREGNANCY

Have you been pregnant in the last 6 months or planning to get pregnant? Yes/ No
Are you currently breast-feeding or have breast fed in the last 6 months? Yes / No

HEALTH

How would you rate your general health………………………………………………………………………………

Do you have any medical conditions? (e.g. heart condition, asthma, diabetes, hypothyroidism)

Yes / No Details
…………………………………………………………………………………………......................................
......

Do you take any prescribed medication?

Yes / No If yes, please give details………………………………………………………………………………………

………
…………………………

Have you had weight loss surgery? (e.g. gastric bypass, stomach stapling)

Yes / No If yes please give details

………………………………...……………………………………………

**………
…………………………**

Have you experienced an eating disorder? (e.g. anorexia nervosa, bulimia nervosa, binge eating disorder)

Yes / No If yes please give details

…………………………………………………………………………………...

……………………………………………………………………………………………………........
....

Are there any other health issues (e.g. medical, physical, mental health etc) that may have an effect on your participation in this research study?

Yes / No If yes please give details

…………………………………………………………………………………...

………
…………………………

You may be required to eat the following foods during the study. Please rate the foods listed in the table below according to how much you LIKE or DISLIKE them.

	Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neutral	Like Slightly	Like Moderately	Like Very Much	Like Extremely
Muesli	❍	❍	❍	❍	❍	❍	❍	❍	❍
Raisins/Sultanas	❍	❍	❍	❍	❍	❍	❍	❍	❍
Honey yoghurt	❍	❍	❍	❍	❍	❍	❍	❍	❍
Apple	❍	❍	❍	❍	❍	❍	❍	❍	❍
Banana	❍	❍	❍	❍	❍	❍	❍	❍	❍
Orange	❍	❍	❍	❍	❍	❍	❍	❍	❍
Melon	❍	❍	❍	❍	❍	❍	❍	❍	❍
Pineapple	❍	❍	❍	❍	❍	❍	❍	❍	❍
Mango	❍	❍	❍	❍	❍	❍	❍	❍	❍
Carrot	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cherry tomato	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cucumber	❍	❍	❍	❍	❍	❍	❍	❍	❍
Lemon chicken risotto	❍	❍	❍	❍	❍	❍	❍	❍	❍
Vegetable lasagne	❍	❍	❍	❍	❍	❍	❍	❍	❍
Chicken curry	❍	❍	❍	❍	❍	❍	❍	❍	❍
Chicken chow mein	❍	❍	❍	❍	❍	❍	❍	❍	❍
Tomato & herb risotto	❍	❍	❍	❍	❍	❍	❍	❍	❍
Porridge	❍	❍	❍	❍	❍	❍	❍	❍	❍

Low-calorie chocolate mug cake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Scotch broth	❍	❍	❍	❍	❍	❍	❍	❍	❍
Vegetable broth	❍	❍	❍	❍	❍	❍	❍	❍	❍
Spaghetti bolognaise	❍	❍	❍	❍	❍	❍	❍	❍	❍
Three cheese pasta	❍	❍	❍	❍	❍	❍	❍	❍	❍
Shepard's pies	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie banana shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie strawberry shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie chocolate shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie vanilla shake	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie peanut crunch bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie toffee chocolate bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Low-calorie fudge nut bar	❍	❍	❍	❍	❍	❍	❍	❍	❍
Strawberry yoghurt	❍	❍	❍	❍	❍	❍	❍	❍	❍
Water	❍	❍	❍	❍	❍	❍	❍	❍	❍
Coffee	❍	❍	❍	❍	❍	❍	❍	❍	❍

Tea	❍	❍	❍	❍	❍	❍	❍	❍	❍

THANK YOU

The information you have provided in this form will be kept strictly confidential.

Would you like us to keep your details on file and contact you about any future studies that we have? **Yes / No**

Appendix 2 VAS Palatability ratings

(1) Part A

Please complete this section, after consuming the foods provided, by placing a vertical mark through the line.

1. How sweet did you find the **RISOTTO**?

Not at all ______________________________ Extremely

Sweet Sweet

2. How savoury did you find the **RISOTTO**?

Not at all ______________________________ Extremely

Savoury

Savoury

3. How fatty did you find the **RISOTTO**?

Not at all ______________________________ Extremely

Fatty Fatty

4. How tasty did you find the **RISOTTO**?

Not at all ______________________________ Extremely

Tasty Tasty

5. How pleasant did you find the **RISOTTO**?

Not at all ______________________________ Extremely

Pleasant Pleasant

6. How filling did you find the **RISOTTO**?

Not at all ____ Extremely
Filling Filling

7. How satisfying did you find the **RISOTTO**?

Not at all ____ Extremely
Satisfying Satisfying

8. How much did you like the **RISOTTO**?

Not at all ____ Extremely

9. How much more of the **RISOTTO** do you think you could eat?

A Small ____ A Large
Amount Amount

Part B

Please complete this section, after consuming the foods provided, by placing a vertical mark through the line.

1. How sweet did you find the **YOGHURT**?

Not at all ____ Extremely
Sweet Sweet

2. How savoury did you find the **YOGHURT**?

Not at all ____ Extremely
Savoury
Savoury

3. How fatty did you find the **YOGHURT**?

Not at all Fatty	________________________________	Extremely Fatty

4. How tasty did you find the **YOGHURT**?

Not at all Tasty	________________________________	Extremely Tasty

5. How pleasant did you find the **YOGHURT**?

Not at all Pleasant	________________________________	Extremely Pleasant

6. How filling did you find the **YOGHURT**?

Not at all Filling	________________________________	Extremely Filling

7. How satisfying did you find the **YOGHURT**?

Not at all Satisfying	________________________________	Extremely Satisfying

8. How much did you like the **YOGHURT**?

Not at all	________________________________	Extremely

9. How much more of the **YOGHURT** do you think you could eat?

A Small Amount	________________________________	A Large Amount