Chapter 1. INTRODUCTION

1.1. Prelude.

A portion is defined as the quantity of food or drink a person would consume on one eating or drinking occasion (Schwartz and Byrd-Bredbenner, 2006). In contrast, a serving size is the amount of food or drink customarily consumed on one occasion and is determined from nationwide food consumption surveys (U.S. Food and Drug Administration [FDA] 1999).

Portion size may be affected by physiological cues such as sensations of hunger and fullness (Mattes, Hollis, Hayes and Stunkard, 2005; Kral, 2006); cognitive factors such as memory of recent eating or expected satiety (ES) (Higgs, 2002; Brunstrom and Shakeshaft, 2009); food or drink attributes such as energy density and macronutrient content (Bell and Rolls, 2001; Almiron-Roig, Chen and Drewnowski, 2003; Ello-Martin, Ledikwe and Rolls, 2005; Mattes et al. 2005; de Graaf, 2006; Burger, Kern and Coleman, 2007); taste, smell, texture and appearance (Sorensen, Moller, Flint, Martens and Raben, 2003; Kral, 2006); environmental influences such as consumption norms, advertising, variety and serving container size (Wansink, 2004; Wansink and Cheyney, 2005; Wansink, van Ittersum and Painter, 2006; Cohen and Farley, 2008) and emotions such as sadness, boredom and anger (Desmet and Schifferstein, 2008).

Hunger refers to the need for food and describes the sensations which occur in response to food deprivation (Herman and Polivy, 2005). Fullness is defined as a sensation of the degree of stomach filling and contributes to satiation and meal termination (Sorensen et al. 2003; Cummings and Overduin, 2007). Perceived satiation (PS) refers to how full a person expects to feel on finishing a food (Irvine, Brunstrom and Rogers, 2008). Energy density is defined as the amount of energy per unit weight of food in kcal/g or kJ/g (Ello-Martin et al. 2005). Investigating how hunger, fullness, PS and energy density influence estimation of portion sizes and accuracy of estimation, compared with reference amounts in portion size guidance schemes, could help develop strategies to tackle overweight and obesity in the adult population (Davis, Curtis, Tweed and Patte, 2007).

1.2. Trends in overweight and obesity worldwide.

Overweight and obesity are associated with an increased risk of diseases, including type 2 diabetes, coronary heart disease and some cancers (Department of Health [DH] 2004). The prevalence of overweight and obesity in England has almost trebled since the 1980s (National Heart Forum [NHF] 2007), where in 2006, estimates showed that 23.7% of men and 24.2% of women were obese and almost two-thirds of adults (61.6%) were either overweight or obese (The Information Centre for Health and Social Care, 2008). In the USA, data from the most recent National Health and Nutrition Examination Survey [NHANES] (2006-2007), indicate that levels of obesity in the USA have reached 33.3% and 35.3% in men and women, respectively (Ogden, Carroll, McDowell and Flegal, 2007). If current trends continue it has been estimated that by 2015, approximately 2.3 billion adults worldwide will be overweight and more than 700 million will be obese (World Health Organization [WHO] 2006). By 2050, Foresight modelling indicates that 60% of British men and 50% of British women will be obese (Foresight, 2007).

1.3. Trends in food portion sizes.

Studies in the USA have shown that the increased prevalence of overweight and obesity has coincided with an increase in the portion sizes of foods and drinks in restaurants, fast-food establishments, supermarkets and convenience stores (Rolls, Roe, Meengs and Wall, 2004b; Wansink and van Ittersum, 2007; Popkin et al. 2006). According to Nestle (2003), the expansion of portions in the USA started as early as the 1970s, increased sharply in the 1980s and has continued to rise. Data indicate that between 1977-2002, major contributors of energy to the US diet, including salty-snacks, chocolate bars, muffins, soft drinks and ready-to-eat cereals have shown significant increases in portion size (Young and Nestle, 2002; Nestle, 2003; Young and Nestle, 2003; Nielson and Popkin, 2003; Smiciklas-Wright, Mitchell, Mickle, Goldman and Cook, 2003). In accordance with these findings, portion sizes of energy dense (ED) foods, caloric beverages and fast-food meals appear to have increased in some European countries such as Denmark, particularly since the 1980s (Matthiesen, Fagt, Biltoft-Jensen, Beck and Ovesen, 2003). In contrast, UK data on trends in food portion sizes, recently reviewed by Church (2008), indicate that the portion sizes of standard and traditional products, e.g. cakes and biscuits, have remained fairly constant over the last 15-20 years. However, the report did identify a clear increase in the range of available portion sizes for many foods and some drinks; in particular for ED premium products, such as American muffins, chocolate confectionary, ice-cream and crisps. In accordance with data from the USA and Denmark, there is also some evidence of increasing food portion sizes being served in UK fast-food outlets (Wrieden, Gregor and Barton, 2008), where it is commonplace to offer 'unlimited refills' of carbonated soft drinks and squash (Church, 2008). However, the lack of directly comparable data on food portion sizes available in the UK has made it difficult to ascertain consistent trends for many food categories (Church, 2008; Institute of Grocery Distribution [IGD] 2008).

1.4. Portion distortion and portion size guidance schemes.

The temporal relationship between increasing food portion sizes and the incidence of obesity has led to the suggestion that larger portion sizes play a role in the aetiology of obesity, particularly in the USA (Rolls, Roe and Meengs, 2007; Jeffery et al. 2007; Rolls et al. 2004c; Young and Nestle, 2002; Rolls, 2003). However, a causal relationship between increasing portion sizes and obesity rates would be difficult to establish, owing to the influence of confounding factors which may contribute to the risk of excess weight gain, e.g. decreased physical activity and increased availability of inexpensive high-calorie foods (Church, 2008; Levitsky and Youn, 2004; Kelly et al. 2008; Rolls, 2003). It has been suggested that **portion distortion** (perceiving large portions as appropriate amounts to eat at a single eating occasion) results in individuals selecting and consuming much larger amounts of food and drink and therefore energy than recommended (Schwartz and Byrd-Bredbenner, 2006; de Graaf, 2006, Burger et al. 2007). Larger-sized packages, restaurant and fast-food portions, along with larger-sized dinnerware have resulted in increased consumption norms, which suggest that it is appropriate, typical and reasonable to serve and consume increasing amounts of food and drink (Condrasky, Ledickwe, Flood and Rolls, 2007; Wansink and van Ittersum, 2007; Wansink, van Ittersum and Painter, 2006; Wansink, 2004; Daggett and Rigdon, 2006). For example, Wansink (1996) showed that when 184 women were presented with various package sizes of spaghetti, oil or chocolate candies, they poured out significantly greater amounts when given a larger package than when given a smaller package. Also, in a later study on self-selected portion sizes of various foods (including snacks) and drinks, 51 university students chose significantly larger portion sizes in 10 of 15 food/beverage items, compared to reference amounts (Burger et al. 2007).

In an effort to improve estimation of appropriate portion sizes, a variety of portion size guidance schemes have been created in the UK and other countries by the Government, industry, non-government organisations and healthcare professionals (IGD, 2008; Anderson et al. 2008). However, people are still unable to accurately estimate appropriate portion sizes of foods and drinks (Yuhas, Bolland and Bolland, 2006; Rolls, 2003; Schwartz and Byrd-Bredbenner, 2006; Burger et al. 2007; Flood et al. 2006) and this is irrespective of body weight (Blake, Guthrie and Smiciklas-Wright, 1989; Wansink and Van Ittersum, 2007; Brunstrom, Rogers, Pothos, Calitri and Tapper, 2008a). This may be due to a lack of communication to the general public on the existence of appropriate portion sizes (Food Standards Agency [FSA] 2008); Anderson et al. 2008), as well as a dissociation between recommended serving sizes and the portions offered to consumers (Rolls, 2003). In addition, since portion size guidance schemes are based on different criteria, (e.g. survey data, nutrient requirements, consumer expectations) and were created for different purposes, (e.g. analyzing dietary intakes, therapeutic diets, food labelling), the quantitative guidance they provide on food portion sizes is inconsistent (IGD, 2008; Ueland, Cardello, Merrill and Lesher, 2009). Examples of portion size guidance schemes include those created by the following organisations: Dietitians in Obesity Management (DOM) UK (2005); the Food Standards Agency (Crawley, 2002); the American Dietetic Association (ADA) (2007) and the US Food and Drug Administration (FDA) (2001). DOM UK (2005) standards are primarily based on energy content of foods and drinks and were created to assist overweight and obese patients with weight loss and weight management. FSA (2002) and FDA (2001) standards are based on amounts customarily consumed per eating occasion in the UK and USA, respectively, and are used in research or added to food labels to allow consumers to compare the nutrient content of similar products. ADA (2007) standards are primarily based on carbohydrate content and were produced for dietary management of diabetes. As a result of the co-existence of different guidance schemes, when calculating the number of portions in a particular food or drink based on these standards, discrepancies are common. For example, a chocolate muffin weighing 140g would be classed as 11.5, 5, 2.5 and 1.5 portions, based on DOM UK, ADA, FDA and FSA standards, respectively. Such inconsistencies in the information provided by portion size guidance schemes have thus made accurate estimation of an appropriate portion size increasingly difficult (Rolls, 2003; Burger et al. 2008; Ueland et al. 2009).

1.5. The effects of increasing portion size and appetite status on energy intake and portion size estimation.

A substantial amount of research has been carried out to investigate the influence of larger food portion sizes on amount consumed and energy intake, particularly in the USA (reviewed in Ledickwe, Ello-Martin and Rolls, 2005; Ello-Martin et al. 2005). Experiments have been carried out in both the laboratory and more naturalistic settings, and investigate foods consumed at mealtimes, as well as snacks (Ello-Martin et al. 2005; Church, 2008). Snacks, such as cakes, ice-cream, chocolate and potato chips are of particular interest as they are often high in energy density and are eaten in addition to meals (de Graaf, 2006). In addition, the frequency of snack consumption has increased in the last decade and this is assumed to be one of the dietary changes that has contributed to the increase in the prevalence of obesity (Jahns, Siega-Riz and Popkin, 2001; Zizza, Siega-Riz and Popkin, 2001). Table 1 provides details of several experiments where increasing portion sizes caused significant increases in energy intakes. Increases in energy intake were observed for up to 11 days in both men and women, of various ages and body weights.

Table 1. Studies examining the effects of varying portion size on energy intake (EI) in adults.

Abbreviations: *BMI,* Body Mass Index (kg/m^2); *ED,* energy density (kcal/g); *EI,* energy intake (kcal); *F,* female; *L,* lean; *M,* male; *NW,* normal weight; *O,* obese; *OW,* over weight; *UW,* under weight; *wk,* week.

Authors	Participants	Study length and setting	Manipulation	Effect on EI
Diliberti, Bordi, Conklin, Roe and Rolls (2004)	180 M and F (UW, NW, OW and O[a])	1 occasion; restaurant meal.	Pasta served in 2 portion sizes (248 or 377g)	EI from pasta and overall meal increased by 43% (172 kcal) and 25% (159 kcal) respectively, with increased pasta portion size (p<0.0001)
Levitsky and Youn (2004)	13 M and F [b]	3 days/wk for 1 wk; laboratory.	4 foods served in different portion sizes (100, 125 or 150% of normal intake)	Total EI increased with increasing portion sizes (698, 863, 971 kcal, respectively; p<0.05)
Rolls et al. (2002)	51 M and F NW and OW; BMI 20-28)	1 day/wk for 4 wks; laboratory	Macaroni cheese served in different portion sizes (500, 625, 750 or 1000 g)	EI from macaroni cheese increased with increasing portion sizes (546, 610, 652 and 708 kcal, respectively; p<0.0001)
Rolls et al. (2004b)	75 M and F (UW, NW, OW and O; BMI<40)	1 day/wk for 4 wks; laboratory.	Submarine sandwich served in different portion sizes (6, 8, 10 or 12 inches)	EI from sandwich increased with increasing portion sizes (575, 703, 771 and 834 kcal, respectively; p<0.0001)
Rolls et al. (2007)	10 F and 13 M (NW and OW; BMI 18-30)	2x 11days; laboratory/ home.	All foods/drinks served as standard portions in one period; amounts increased by 50% in other	Mean (±SD) daily EI increased significantly (423 ± 27 kcal) with a 50% increase in portion size (p<0.0001). Intake sustained over 11 days.
Rolls, Roe and Meengs (2006b)	32 M and F (NW and OW; BMI 20-29)	2 days/wk for 3 wks; laboratory/ home.	Various foods, snacks and drinks served in different portion sizes (100, 150 or 200%)	EI increased with increasing portion size and increases were sustained over 2 days (50% and 100% increases in portion size led to 16% and 26% increases in EI respectively, in both sexes; p<0.0001)
Rolls, Roe, Kral, Meengs and Wall (2004a)	60 M and F (NW, OW and O; BMI 20-40)	1 day/wk for 5 wks; laboratory.	Potato chips served in different portion sizes (28, 42, 85, 128 or 170 g)	EI from potato chips increased with increasing portion sizes (138, 196, 297, 359 and 377 kcal, respectively; p<0.0001)

[a]Subject weights estimated by authors; [b]Recruitment criteria for body weight not specified.

Despite the large differences in food and energy intake which occur with increasing portion sizes of meals and snacks, subjects rarely report significant differences in feelings of hunger and fullness post intake (Rolls et al. 2002; Rolls et al. 2004b; Kral, Roe and Rolls, 2004; Rolls, Roe and Meengs, 2006a). Also, in studies where subjects report feeling more full and less hungry after increased food and energy intake, they do not adjust their intake at subsequent meals as a means of compensation (Rolls et al. 2004a; Rolls et al. 2006b; Rolls et al. 2007; Marmonier, Chapelot, Fantino and Louis-Sylvestre, 2002). Evidence suggests that this is due to strong environmental food cues (e.g. increased availability of highly palatable foods in large portion sizes), which can easily override weaker physiological satiety cues, once regarded as the most important determinants of food intake (Herman, Polivy and Leone, 2005; Jebb, 2005; Rolls, 2003). Pre-meal surges in circulating levels of the orexigenic (hunger) hormone ghrelin can also lead to substantial increases in food intake at mealtimes (Cummings and Overduin, 2007). Due to repeated bouts of energy deprivation, which have occurred throughout much of human history, human beings have become very responsive to sensations of hunger and thus poorly equipped to deal with the wide range of food cues which exist in the 21st century (Jebb, 2005; Davidson, Kanoski, Walls and Jarrard, 2005). However, it is possible that decisions about appropriate portion size made prior to meal onset may be sensitive to sensations of hunger and fullness. A study of 55 female students, aged 19-52 years, showed estimation of typical portion size was significantly larger in three of four foods (chips, rice and cheesecake) when subjects were hungry compared with when they were full ($p<0.05$) (Beasley, Hackett, Maxwell and

Stevenson, 2004). Hunger levels were assessed using ten-point hunger-satiety scales prior to portion size estimates, which, under fed conditions, were carried out after consumption of a standard sized Mars bar and 330 ml can of Pepsi. In another study, the effect of hunger on estimation of typical portion size was investigated in the absence of a preload. Hunger levels in undergraduate students (88 females and 63 male) were assessed using 100 mm VAS scales after estimating usual portion sizes of 12 foods from food photographs. Results showed that participants who rated themselves as hungry perceived their usual portion sizes as being significantly larger in 9 of 12 foods ($p<0.05$), compared with those participants who rated themselves as not hungry (Brunstrom et al. 2008a). However, methods to standardise sensations of hunger and fullness were not employed in either study, and VAS scale cut-offs used to distinguish between the presence and absence of hunger were not stated.

Although a substantial amount of research has been carried out to investigate the influence of increasing portion sizes on energy intake from foods, the effect of increasing beverage portion sizes on energy intake is not well understood (Flood et al. 2006; Church, 2008). In a study by Flood et al. (2006), which investigated the impact of increasing beverage portion sizes of cola, diet-cola and water on beverage and energy intake, increasing beverage portion size significantly increased the weight of the beverage consumed, regardless of the type of beverage served ($p<0.05$). As a consequence, for the caloric beverage condition, energy intake from the beverage increased by 10% in women and 26% in men with a 50% increase in beverage portion size ($p<0.01$). Since food intake did not differ between conditions, this resulted in a significant increase in total energy intake at lunch, compared with non-caloric beverages (p<0.001). These findings are important in the light of several studies that have pointed to an increase in the availability of larger beverage portion sizes (Popkin et al. 2006; Church, 2008; Nestle, 2003; Young and Nestle, 2003; Matthiesen et al. 2003). The temporal association between growing consumption of sugar-containing beverages and the rise in obesity rates has already raised the issue that the provision of energy in liquid form may play a role in the obesity epidemic (Mattes and Campbell, 2009; Malik, Schulze and Hu, 2006; Almiron-Roig et al. 2003; Popkin et al. 2006; Nielson and Popkin, 2004). One possible explanation is that energy-containing beverages tend to be less satiating than solid foods (Mattes and Campbell, 2009; Drewnowski and Bellisle, 2007; Popkin et al. 2006; Tsuchiya, Almiron-Roig, Lluch, Guyonnet and Drewnowski, 2006; Flood et al. 2006). The absence of chewing and the increased rate of stomach emptying associated with liquids may cause diminished gastric and post-gastric responses post ingestion, thus leading to deficits in satiety compared with solid foods (reviewed in Almiron-Roig et al. 2003). As a result, consumption of energy-containing beverages, even in large portion sizes, does not always lead to adjustments in food and/or beverage intake as a means of dietary compensation (Mattes and Campbell, 2009; Mourao, Bressan, Campbell and Mattes, 2007; Jebb, 2005; McCrory, Suen and Roberts, 2002; Popkin et al. 2005; Mattes et al. 2005; Flood et al. 2006; Rolls et al. 1990; DellaValle, Roe and Rolls, 2005; Almiron-Roig and Drewnowski, 2003; Almiron-Roig et al. 2003; Kim and Federoff, 1990). Despite this, studies have shown that varying the volume of a liquid administered prior to food intake can influence the amount of energy consumed at that meal. In a study by Rolls, Bell and Waugh (2000), participants consumed significantly less energy at lunch after a 600 ml yoghurt-based milk shake preload, compared with a 300 ml preload, identical in nutrient and energy content. This effect of increasing volume on reducing energy intake may have occurred for various reasons. To begin with, protein contained in milk and yoghurt may be more satiating than sugar contained in sweetened carbonated drinks, such as cola (Tsuchiya et al. 2006). Indeed, milk has been characterized as 'food that you can drink' and thus capable of triggering satiety mechanisms, whereas sweetened beverages are seen primarily as thirst-quenching liquids with little or no satiety (Rolls and Barnett, 2000). In addition, milk/yoghurt based drinks are more viscous than carbonated beverages and several studies have reported that viscous preloads can suppress hunger more effectively than preloads of thinner consistencies (Tsuchiya et al. 2006; Mattes and Rothacker, 2001). Finally, in the study by Rolls et al. (2000), the milk shake was provided as a preload and ingested over a 15 minute period prior to the provision of the lunch meal. In the study by Flood et al (2006) beverages were provided alongside rather than prior to the lunch meal. The time lag between liquid consumption and onset of food intake in the former study may have allowed gastric distention and secretion to evoke feelings of fullness, thus explaining why energy compensation was evident at the following meal (Almiron-Roig et al. 2003). Therefore, despite the fact that sweetened beverages are low in energy density (0.6-1.4 kcal/g or ml) (Rolls and Barnett, 2000), consumption of these energy-containing beverages could lead to excess energy intake within and outside the context of the three main meals (Mourao et al. 2007; de Graaf, 2006). However, since reported links between sweetened beverage consumption and weight gain are based on temporal parallel and cross-sectional studies, a causal link between beverage intake and obesity rates has yet to be established (Drewnowski and Bellisle, 2007; Drewnowski, Almiron-Roig, Marmonier and Lluch, 2004; Bachman et al. 2006).

1.6. The effects of energy density and caloric beverages on energy intake and accuracy of portion size selection.

In addition to portion size, the energy content of foods and drinks has been shown to directly influence short-term energy intake, independent of portion size (Ello-Martin et al. 2005; Kral and Rolls, 2004; Westerterp-Plantenga, 2004; Burger et al. 2007). Studies have indicated that individuals consistently consume more energy when presented with foods of a higher energy density and caloric drinks, compared with similar foods of a lower energy density or water, respectively (Ledickwe et al. 2005; Bell, Castellanos, Pelkman, Thorwart and Rolls, 1998; Bell and Rolls, 2001; Rolls et al.1999a; DellaValle, Roe and Rolls, 2005; Almiron-Roig and Drewnowski, 2003). This is because the body is incapable of accurately monitoring the calories in foods and drinks (Westerterp-Plantenga, 2004; Wansink and van Ittersum, 2007) as supported by the absence of differences in ratings of hunger and fullness when people have consumed foods or drinks of a similar volume with varying energy densities (Bell, Castellanos, Pelkman, Thorwart and Rolls, 1998; Bell and Rolls, 2001; Rolls et al.1999a; DellaValle, Roe and Rolls, 2005; Almiron-Roig and Drewnowski, 2003). Instead physiological mechanisms, such as gastric distension and emptying; consumption norms, such as portion size; and expected fillingness seem to be stronger determinants of appropriate amounts of food and/or drink to consume at any one eating occasion (Kral and Rolls, 2004; Wansink and van Ittersum, 2007; Westerterp-Plantenga, 2004; Brunstrom and Shakeshaft, 2009). As a result, the energy content of foods and drinks act as direct determinants of energy intake (Kral et al. 2004; Kral and Rolls, 2004; Westerterp-Plantenga, 2004; de Graaf, 2006). Thus, increasing consumption norms, the poor satiating power of energy containing beverages and the perceived low filling capacity of HED foods (Wansink and van Ittersum, 2007; Wansink, 2004; Almiron-Roig et al. 2003; Popkin et al. 2006; Brunstom et al. 2008b; Brunstrom and Shakeshaft, 2009) can result in passive over consumption of these foods and drinks (Jebb, 2005; Kral et al. 2004; Rolls et al. 2006; Flood et al. 2006). In addition, the ready availability of highly palatable foods in Western society may also lead to over eating (Yeomans, Lee, Gray and French, 2001; Yeomans, Blundell and Leshem, 2004).

Table 2 describes five studies where increasing the energy density of meal entrees or consuming caloric, as opposed to non-caloric drinks, caused significant increases in energy intake at meal times. Meal entrees were matched for palatability and effects were seen across various ages and body weights. Tests were predominantly carried out in females, although one study involved male participants (Almiron-Roig and Drewnowski, 2003). Overall, results indicate that consuming foods with higher energy densities and caloric drinks does not lead to energy compensation at subsequent meals.

Table 2. Studies examining the effects of varying energy density on energy intake in adults.

Abbreviations: *BMI,* Body Mass Index (kg/m^2); *ED,* energy density (kcal/g); *EI,* energy intake (kcal); *F,* female; *L,* lean; *M,* male; *NW,* normal weight; *O,* obese; *OW,* over weight; *wk,* week.

Authors	**Participants**	**Length of study**	**Manipulation**	**Effect on amount consumed or EI**
Bell et al. (1998)	18 F (NW, BMI 19-26)	2 day/wk for 3 wks	Main entrees varied in ED at lunch, dinner and evening snack (0.8, 1.1 or 1.3 kcal/g)[1]	Daily EI increased with level of ED of entrees (1376, 1519 and 1800 kcal, respectively; p<0.0001)
Bell and Rolls (2001)	36 F (L and O; BMI 20-25 and 28-48, respectively)	1 day/wk for 6 wks	Main entrees varied in ED (1.25 and 1.75 kcal/g) and fat content (25, 35 and 45%) at breakfast, lunch, dinner and supper[2]	Daily EI increased with level of energy density of entrees, from 1799 to 2250 kcal, respectively, across all fat contents (p<0.0001)
Rolls et al. (1999a)	34 F (L and O; BMI 20-24.9 and ≥30, respectively)	4 days/wk for 3 wks	Main entrees, comprising 50% of average intake, were compulsory and varied in ED (1.1 and 1.6 kcal/g) and fat content (16% and 36%) at breakfast, lunch and dinner[3]	Daily EI increased with level of energy density of entrees in obese women only, from 2330 to 2515 kcal/d, respectively (p<0.05), with no effect of fat content
DellaValle et al. (2005)	44 F (NW, OW and O; BMI 20-40)	1 day/wk for 6 wks	Lunch was served with a caloric beverage[4], a non-caloric beverage[5], or no beverage at all	EI at lunch was significantly higher when served with a caloric beverage, compared with the non-caloric or no beverage conditions (p<0.0001)
Almiron-Roig and Drewnowski (2003)	14 M and 18 F (NW; BMI 20-27)	1 day/wk for 4 wks	A breakfast preload was served with one of 3 caloric beverages[6] or water, followed by lunch served ad libitum	Total EI was significantly higher in the 3 caloric-beverage conditions, compared with water (p<0.001)

[1]Two different menus were provided at each 2 day test session. Lunch entrees were either pasta salad with Italian dressing or pasta salad with yoghurt dressing; dinner entrees were either Italian pasta bake or chicken noodle casserole; evening snack entrees were smaller portions of either of the pasta salads served at lunch. Entrees were matched for ED according to condition.

[2]Entrees served at each meal consisted of multiple food and drink items, matched for ED and fat content, according to condition.

[3]A different menu was provided on each day of the 4 day test sessions. Entrees, consisting of multiple food and drink items, varied at each meal and on each menu, but were matched for energy and fat content according to condition.

[4]Caloric beverages cola, orange juice, or milk contained 156 kcal per serving.

[5]Non-caloric beverages were diet-cola or water.

[6]Caloric beverages were cola, orange juice or milk, containing 248 kcal per serving and were accompanied by 1 slice of toast (100 kcal).

In addition to research investigating the effects of energy density and caloric beverages on energy intake, work has also been carried out to examine self-selected portion sizes of ED foods and liquids, compared with reference amounts. Burger at al. (2007) examined self-served portion sizes of foods and drinks in 51 males and females, compared with reference portion sizes from the US Food and Drug Administration (FDA) (2001). The results showed absolute differences between servings of high ED foods and reference amounts were significantly larger than differences seen with servings of LED foods ($p<0.01$). However, beverage serving sizes showed the greatest absolute differences of all items included in the study, compared with reference amounts.

1.7. The effects of food type and amount displayed on portion size estimation and selection.

The studies discussed previously have shown that energy intake increases with increasing portion size and energy density, irrespective of the amount of food available or the food type, i.e. amorphous foods, defined as foods with an undefined shape (Rolls et al.2002; Kral et al. 2004); discrete foods, defined as foods with a clearly defined shape (Rolls et al. 2004b), liquids (Flood, Roe and Rolls, 2006) and packaged foods (Rolls et al. 2004a). In contrast, estimation and selection of typical food portion size appears to be affected by amount displayed (Blake et al. 1989) and food type (solid, liquid or amorphous) (Weber et al. 1999), where the size of amorphous foods and liquids may be estimated more inaccurately than solids

(Bolland, Ward and Bolland, 1990; Burger et al. 2007), or vice versa (Blake et al. 1989.

1.8. The effects of dietary learning on energy intake and estimation of prospective portion size.

Previous studies have shown that compensatory adjustments in energy intake do not occur with increasing portion sizes of food or drink, even where increased portion sizes have coincided with increased ratings of fullness (Rolls et al. 2004a; Rolls et al. 2006b; Rolls et al. 2007; Marmonier, Chapelot, Fantino and Louis-Sylvestre, 2002; Mattes et al. 2006; Flood et al. 2006; Rolls et al. 1990; DellaValle, Roe and Rolls, 2005; Almiron-Roig and Drewnowski, 2003). In contrast, memory for what has been eaten recently has been shown to elicit adjustments in food intake (Higgs, Williamson and Attwood, 2008; Higgs, 2002; Polivy, Herman, Hackett and Kuleshnyk, 1986). This is because food intake is not solely determined by physiological mechanisms (Desmet and Schifferstein, 2008; Brunstrom, 2004), but instead is influenced by a combination of factors, including cognitive cues (Higgs et al. 2008; Gibson and Brunstrom, 2006; Higgs, 2002). Learned satiety is one of several forms of dietary learning in which exposure to a novel food is thought to create an association between the sensory characteristics of that food and its post-ingestive consequences (Brunstrom, 2004; Gibson and Brunstrom, 2006).When the food is high energy density, its sensory properties can come to signal this fact and food intake is adjusted accordingly (Brunstrom and Wilkinson, 2007).

The first evidence of learned satiety in man was provided by Booth et al. (1976) (Gibson and Brunstrom, 2006). Participants were given a lemon-flavoured drink containing high (65%) or low (5%) levels of starch, but matched for palatability, followed by a novel-tasting yoghurt. The flavour of the yoghurt paired with the 65% starch drink was different to the flavour paired with the 5% starch drink. Initially, lunch intakes after each type of drink did not differ, but with repeated exposure, food intake following the high starch and thus energy drink was significantly reduced ($p<0.05$). Furthermore, when the energy of the drink was equated at 35%, participants still ate significantly less at lunch after consumption of the yoghurt previously paired with the high energy drink ($p<0.01$) (Booth et al. 1976).

Since the study carried out by Booth et al. (1976), several studies on learned satiety in adults have shown incomplete or total lack of energy compensation on exposure to flavours previously and repeatedly paired with foods or drinks high in energy density (Brunstrom, 2007; Zandstra, Stubenitsky, de Graaf, and Mela, 2002; Brunstrom and Wilkinson, 2007; Brunstrom and Mitchell, 2007). However, since studies on portion size have shown that food intake is governed by the amount of food initially placed on a plate or in a package (Table 1), the most important determinant of energy intake may be a brief period of cognitive activity during which people select a portion size prior to consumption (Brunstrom, 2007; Brunstrom, Shakeshaft and Scott-Samuel, 2008b; Brunstrom and Shakeshaft, 2009; Brunstrom, 2008). Part of this process will involve an expectation about the extent to which a food and food portion size is likely to be regarded as satisfying, once the meal has terminated (Brunstrom, 2007). Thus, rather than influencing our behaviour towards the end of a meal, learned associations might be more likely to promote the planning of portion-sizes prior to meal onset (Brunstrom, 2007).

Expected satiety (ES) is the concept that a portion of food will deliver enough satiety to stave off hunger until the next meal (Brunstrom and Shakeshaft, 2009). A recent study by Brunstrom et al. (2008b) measured the ES of 18 foods in 76 participants and found that expectations about satiety differed markedly across foods. High energy dense foods were expected to be significantly less filling than foods of lower energy densities. Also, foods rated as more familiar, i.e. those consumed most often, were expected to be more filling than less familiar foods, irrespective of macronutrient content and energy density. ES was quantified by asking subjects to compare 40 photographs of each test food with a standard food, always presented as a 200 kcal portion. Photographs were presented on a computer screen in increasing weights, where picture one was 0.1 times the weight of the standard food and picture forty was four times that of the standard. For each standard-comparison pairing, subjects were instructed to “Imagine you were having one of the food portions for lunch and won’t be eating again until 6pm. Which of these two food portions would stop you feeling hungry for the longest?” Participants then selected the photograph of the food which they felt would stave off hunger for the longest period. The results of the selections were used to calculate ratios of ES for each food, where ratios higher or lower than 1.0 indicated that the comparison food was considered more or less filling than the standard food, respectively. Measures of ES of the foods used in the study were found to be significantly associated with measures of actual satiety, as determined by Holt's Satiety Index (Holt, Miller, Petocz, and Farmakalidis, 1995). In accordance with previous research, this suggests that humans are well able to conceive expectations about the post-ingestive consequences of consuming food (Green and Blundell, 1996; de Graaf, Stafleu, Staal and Wijne, 1992; Brunstrom et al. 2008b). However, it was not until recently, in a study by Brunstrom and Shakeshaft (2009), that the relationship between ES and prospective portion size was investigated for the first time. This study, involving 60 participants, revealed a significant association between ES and prospective portion size in 8 snack foods, irrespective of hunger and fullness. Specifically, foods that had higher ES ratios were chosen in smaller portion sizes. However, since 7 of the 8 foods were high in energy density (≥ 4.0 kcal/g or ml), it was not possible to investigate and compare ES ratios, prospective portion size and the relationship between the two, with foods of lower energy densities. However, the study did reveal a significant effect of food liking on prospective portion size, which was unrelated, but equal to the effect of ES.

1.9. Critical analysis of previous research and existing gaps in the knowledge.

Several studies have explored the effects of increased fullness, associated with increasing food portion size, on adjustments in food intake at subsequent meals (Rolls et al. 2004a; Rolls et al. 2006b; Rolls et al. 2007; Marmonier, Chapelot, Fantino and Louis-Sylvestre, 2002). Research has also been carried out to investigate the effects of increasing beverage portion size on energy compensation, despite the failure of energy-containing beverages to elicit variations in hunger and fullness under these conditions (Mattes et al. 2006; Flood et al. 2006; DellaValle, Roe and Rolls, 2005; Almiron-Roig and Drewnowski, 2003). In both cases, irrespective of appetite status, adjustments in energy intake were not evident in studies involving either food or drinks. However, little research has been carried out to determine whether hunger and fullness exert different effects on food/drink portion size estimation, or accuracy of estimation, compared with reference amounts in portion sizes guidance schemes. Limitations of previous studies include failure to standardise food intake prior to preload and/or test (Beasley et al. 2004; Brunstrom et al. 2008a). This may have resulted in undetected variations in subjects' baseline appetite levels, which, due to their subjective nature, are difficult to assess accurately with appetite scales (Flint, Raben, Blundell and Astrup, 2000; Kral, 2006). Also, where preloads were administered, there was no wait time between preload consumption and estimation of portion size under fed conditions. This is necessary to allow stomach distension and gastric secretion to evoke feelings of fullness (Brand, Cagan and Naim, 1982). In addition, despite reports that hunger significantly increased portion size estimation in both studies, the effect of hunger on portion size estimates at the time of test was not accurately assessed. Participants were asked, 'How hungry are you right now?' and then told to indicate the portion size they would 'typically' eat, rather than the portion size they could eat at that moment in time. Other limitations included the absence of drinks, failure to compare typical portion sizes with reference amounts in portion size guidance schemes and use of food photographs, which may be a less accurate means of quantifying actual portion sizes than using real foods (Ovaskainen, 2000; Lilllegaard, Overby and Andersen, 2005; Faggiano et al. 1992).

Foods with high energy densities and caloric drinks have been shown to significantly increase energy intakes in several studies (Bell et al. 1998; Bell and Rolls, 2001; Rolls et al.1999a; DellaValle et al. 2005; Almiron-Roig and Drewnowski, 2003). However, little research has been carried out to investigate the effects of ED foods and caloric drinks on accuracy of portion size estimation. In the study by Burger at al. (2007) differences between self-selected portion sizes and FDA standards were reported as absolute values, making it impossible to establish differences in the direction of inaccuracies of portion size estimates amongst foods and drinks. Also, energy density was considered high or low according to whether it fell above (high) or below (low) the mean energy density of all foods used in the study, thirst was not assessed before self-selection of portion size and amounts selected were only compared with reference amounts from one portion size guidance scheme.

ES and its effects on prospective portion size have been investigated previously (Brunstrom et al. 2008b; Brunstrom and Shakeshaft, 2009). In summary, problems with previous studies on ES include use of food photographs, rather than real foods; the absence of drinks and LED foods; a failure to control food intake prior to test and variations in the time of day at which tests were carried out. In contrast, little research has been carried out to investigate the effects of PS on estimation of food/drink portion sizes. A study carried out by Irvine et al. (2008) showed a significant difference in PS between 7 different foods (staples, snacks and treats), where treats were expected to confer the least satiation. Unfortunately, the abstract did not provide details of the actual foods used or specify measures of PS in those foods. However, unpublished data appear to suggest that measures of PS and ES are reasonably well correlated (Brunstrom and Shakeshaft, 2009). Despite this, no research has been carried out to determine whether considering PS prior to portion size estimation alters portion size estimates or accuracy of estimation, compared with reference amounts in portion sizes guidance schemes. Investigating PS and its effects on portion size estimation may help to explain why certain foods/drinks are selected and consumed in larger portion sizes (Brunstrom, 2008). Also, since self-selected meals tend to be consumed in their entirety, it is possible that considering PS prior to meal onset may be a useful way to control portion size selection and thus energy intake (Brunstrom, 2007; Brunstrom, 2008; Brunstrom and Shakeshaft, 2009).

1.10. Aims, objectives and hypotheses.

Based on the information presented above and in light of the existing gaps in the literature, this study aims at investigating the effects of appetite status and PS on estimation of food/drink portion sizes in adult males and accuracy of estimation compared with standard portion sizes in portion size guidance schemes. In addition, the study will also compare accuracy of portion size estimates in foods with varying energy densities and caloric drinks.

The study objectives are:

(a) To investigate if hunger and fullness exert different effects on estimation of food/drink portion sizes and accuracy of portion size estimation compared with reference amounts.

(b) To investigate the effects of employing a PS cue on:

i) estimation of portion size and accuracy of estimation in foods with varying energy densities and drinks.

ii) interaction of PS with appetite status.

(c) To investigate if accuracy of portion size estimation is different in foods with high energy densities and caloric drinks, compared with foods of lower energy densities.

The study will be carried out in men using Visual Analogue Scales (VAS) to measure hunger, fullness and PS and questionnaires to measure portion size estimates. Portion size estimates will be compared with actual portion sizes based on DOM UK, FSA, ADA and FDA standards.

The study hypotheses are:

(a) Being full results in a larger and more accurate estimation of food/drink portion size than being hungry.

(b) Considering PS prior to portion size estimation increases portion size estimates and accuracy of estimation, especially in foods with lower energy densities.

(c) Portion sizes of high ED foods and caloric drinks are estimated less accurately than portion sizes of foods lower in energy density.

It was also hypothesised that PS and appetite status may interact, but the nature of this interaction cannot be predicted.