# Chapter 4. DISCUSSION.

## 4.1. Summary of results.

In this study, portion size estimates for popular snack foods/drinks were significantly smaller when male subjects were hungry compared with when they were full ($p<0.01$).

Accuracy of estimation decreased under hungry conditions for all foods/drinks tested with respect to health professional standards (DOM UK and ADA). This was also true with reference to government standards (FSA and FDA), except for the banana.

Perceived fillingness had no significant effect on food/drink portion size estimates or accuracy of estimates according to any of the standards.

Percentage error of portion size estimates increased with increasing energy density ($r = 0.36$, $n = 32$, $p<0.05$), although the relationship failed to reach significance in the absence of drinks ($r = 0.40$, $n = 24$, $p=0.05$).

## 4.2. Appetite sensation ratings.

Overnight fasting minimised between-subject differences in levels of hunger and fullness at baseline, as expected. Also, between-subject differences in thirst ratings at baseline were not significant. However, following the breakfast pre-load, within-subject ratings of hunger, fullness and thirst increased significantly under conditions F and FPS, as expected. This confirmed that subjects estimating portion sizes under hungry conditions (H and HPS) were significantly more hungry, less full and more thirsty, than subjects estimating portion sizes under full (F and FPS) conditions, thus confirming the effect of the breakfast intervention.

Differences in thirst under full and hungry conditions may have affected estimation of beverage portion sizes. Higher levels of thirst under hungry conditions may have enhanced the effect of the hunger condition on beverage portion size estimates, causing greater differences between estimates of beverage portion sizes under full and hungry conditions, as compared with foods. However, in a study by McKiernan, Hollis, McCabe and Mattes (2009), data showed that thirst ratings and consumption of energy-yielding beverages were not related. This suggests that in the present study, higher levels of thirst under hungry compared with full conditions would not have enhanced the effect of the hunger condition on estimation of beverage portion sizes, as compared with foods. This is confirmed by the fact that, despite within-subject variations in thirst ratings under full and hungry conditions, differences in portion size estimates between conditions were significant for foods and drinks, rather than for drinks alone.

### 4.3. The effects of appetite status on portion size estimates.

The results of this study demonstrate that food portion size estimates are larger under full (compared with hungry) conditions, as stated in the hypotheses. This suggests that decisions about portion size made prior to meal onset are sensitive to sensations of hunger and fullness, as demonstrated by Beasley et al. (2004) and Brunstrom et al. (2008a) (See Introduction, section 1.5). In the present study, measures of perceived satiation (PS) showed that test foods and drinks were considered to be more filling when people were full compared with when they were hungry, despite actual portion sizes being maintained across conditions. Therefore, since expectations of satiation increased in test foods/drinks under full conditions, it is logical to expect that portion sizes would be perceived as larger when people were full compared with when they were hungry.

However, although the overall effect of fullness on portion size estimates was significant in all test foods/drinks, differences in estimates between conditions were more prominent in HED foods (chocolate bar, muffin and crisps) and drinks, than in either of the MED foods (cornflakes and ice-cream) or the banana (LED). These results provide support for work carried out by Burger et al. (2007) who demonstrated that HED foods and drinks are estimated with less accuracy than LED foods. However, due to the limited number of foods/drinks included in this study, further research is required to investigate the effects of energy density and food form (liquids vs. solids) on portion size estimation.

### 4.4. The effects of appetite status on accuracy of portion size estimates.

With reference to health professional standards (DOM UK and ADA), portion sizes of all foods and drinks were perceived with greater accuracy when subjects were full compared with when they were hungry, as proposed in the hypotheses. This was also true when comparing portion sizes of test foods and drinks to government standards (FSA and FDA), except for the banana. With respect to these standards, the banana was estimated with greater accuracy under hungry conditions. However, this was due to the fact that the actual portion sizes of the banana according to FSA and FDA standards were 0.8 and 0.5, respectively. Therefore, since mean portion size estimates for the banana were 1 and 0.8 under full and hungry conditions, respectively, this resulted in the banana being estimated correctly or overestimated according to FSA and FDA standards. Thus, in effect, the positive direction of the inaccuracies caused the smaller estimate under hungry conditions (0.8) to appear more accurate than the larger estimate under full conditions (1), with respect to government standards. This did not occur with any of the other test foods and drinks, or the banana based on health professional standards. In these cases, actual portion sizes were greater than or equal to estimates, causing inaccuracies to occur in a negative direction. In turn, this resulted in smaller estimates under hungry conditions being more inaccurate than larger estimates under full conditions.

Comparison of test foods/drinks with all four standards showed that the banana was the only item that was overestimated. However, this cannot be explained by expectations of fillingness according to energy density. In a study by Brunstrom et al. (2008b) measures of ES in 18 common foods showed that foods with high energy densities were expected to be significantly less filling than foods of lower energy densities. In contrast, in the present study and despite the fact that unpublished data suggest ES and PS are reasonably well correlated (Brunstrom and

Shakeshaft, 2009) PS was shown to increase with increasing energy density. This may explain why the banana (LED) was perceived as the least filling of all the test foods (see Results, Figure 13), but does not explain why it was the only food to be overestimated. However, it important to note that the banana was only overestimated with respect to government standards, but not with reference to standards created by health professionals. This suggests that overestimation was likely due to variations in actual portion size of the banana according to each standard and not characteristics of the banana itself. Actual portion size of the banana with respect to DOM UK, FSA, ADA and FDA standards was 2, 0.8, 1 and 0.5, respectively. Therefore, since the modal estimate was 1, it is logical to assume that the banana was more likely to be overestimated with respect to standards where actual portion size of the banana was less than 1, i.e. FSA and FDA. In contrast to the banana, actual portion sizes of the remaining test foods/drinks in the study were greater than 1 and therefore more likely to be under, rather than over estimated.

When portion size estimates for each food and drink were compared with actual portion sizes based on all four standards, results showed significant discrepancies between subjects' perceptions of a portion size and recommended amounts in schemes created by health professionals. This was also true when comparing portion size estimates with amounts customarily consumed by the public, as detailed in goverment standards. As mentioned previously, except for the banana, discrepancies were always due to underestimates, irrespective of the standard used.

In addition to being the only food which was overestimated, the banana was also the only food/drink to be estimated correctly. This may be explained by the fact that participants considered the banana to be more familiar than any of the other test foods/drinks in the study, thus making it easier to estimate. However, another possible explanation for the banana being estimated correctly is that foods of lower energy densities, such as bananas, are estimated with more accuracy than HED foods and drinks, as shown by Burger et al. (2007). In agreement with these results, the present study showed that percent error of estimates tended to increase with increasing energy density. However, percentage variance showed that energy density was responsible for only 13% of the variance in percent error values. Therefore, since research shows that accuracy of estimation decreases with increasing portion size (Rolls, 2003; Davis et al. 2006; Wansink, 2007), it is logical to assume that weight of test items may also have affected accuracy of estimates. Surprisingly, results showed no relationship between weight of test foods/drinks and percent error. However, in contrast, percent error of estimates was shown to increase with increasing energy load. Energy load was responsible for 15% of the variance in percent error of estimates and may explain why the banana, which had the lowest energy load, was the only food to be estimated correctly. However, it is important to note that the banana was only estimated correctly with respect to FSA and ADA standards and according to these standards, actual portion size of the banana was 0.8 and 1, respectively. In contrast, actual portion sizes of all other test foods and drinks in the study were greater than 1. Therefore, since the modal estimate was 1 and estimates were smaller under hungry conditions, the chances of the banana being estimated correctly were greater than for any of the other test foods/drinks in the study.

### 4.5. Accuracy of portion size estimates and portion size guidance schemes.

When comparing portion size estimates of foods/drinks to actual portion sizes based on each of the four portion size guidance schemes, the two government standards (FSA and FDA) were associated with lower levels of error than the health professional standards (ADA and DOM UK). This is because actual portion sizes based on government standards were generally smaller than actual portion sizes based on health professional standards, likely due to differences in the criteria on which standards are based; FSA and FDA standards are based on amounts customarily consumed per eating occasion, whilst DOM UK and ADA standards are based on recommended amounts. Since FSA standards are based on typical portion sizes consumed in the UK, it was expected that portion size estimates would most closely reflect actual portion sizes based on this scheme alone, rather than both government schemes. However, due to an increase in the range of portion sizes now available in the UK (Church, 2008), it is possible that data used to create FSA standards no longer provides the most accurate reflection of portion sizes customarily consumed in the UK.

When comparing all four standards, the standard associated with the highest levels of error was DOM UK. This was likely due to the fact that DOM UK standards are based on energy load, whilst FSA, ADA and FDA standards are based on weight. Energy load of test foods ranged from 76 to 1225kcal. Weight of test foods ranged from 63 to 520g. Therefore, the range of actual portion sizes according to DOM UK standards was much larger (2 to 24.5) compared with the range of actual portion sizes based on FSA, ADA and FDA standards (0.8 to 5.5, 1 to 7 and 0.5 to 5, respectively). Since mean portion estimates ranged from 0.8 to 2.6, it is logical to expect that inaccuracies would be greater when comparing estimates with actual portion sizes based on DOM UK standards. This effect would have been enhanced by the fact that DOM UK was associated with the largest actual portion sizes for each food and drink overall.

### 4.6. The effects of energy density, weight and energy load on PS ratings.

According to Brunstrom et al. (2008b) foods of lower energy densities such as bananas have higher expected satiety (ES) ratios than energy dense foods and are thus expected to be more filling. In contrast, results from the present study show that perceived satiation (PS) increases with increasing energy density, despite suggestions that ES and PS are reasonably well correlated (Brunstrom and Shakeshaft, 2009). However, in the present study energy density was only responsible for a small percentage of the variation in PS ratings. One possible explanation for this is that PS ratings were affected by weight of the test foods, which was greater in HED foods. Indeed, research indicates that satiety increases with increasing weight (Holt, Miller, Petocz and Farmakalidis, 1995; Drewnowski, 1998). This was confirmed in the present study where PS ratings increased with the weight of the test foods, irrespective of appetite status. Percentage variance showed that weight of test food was responsible for 16% and 19% of the variance in PS ratings under full and hungry conditions, respectively, thus indicating that weight had a greater influence on PS ratings than energy density. This may partly explain why the banana was perceived as the least filling food, despite the fact that it had the lowest energy density. In the study by Brunstrom et al. (2008b) expectations of satiety (ES) were measured in foods presented in similar sizes. Therefore, measures of ES according to energy density would not have been affected by amount displayed, as with measures of perceived satiation (PS) in the present study. However, weight of test food was not the only factor which affected PS ratings in the present study. This is confirmed by between-foods comparisons of PS ratings, which showed that the cornflakes (MED), displayed in the smallest amount (63g), were perceived as more filling than the banana (80g), chocolate bar (85g) and muffin (140g). Therefore, other factors beyond energy density and weight must play a role in expectations of fillingness. Further analyses revealed that PS ratings increased with increasing energy load as well as energy density and weight, and percentage variance confirmed that energy load was responsible for 22% and 25% of the variance in PS VAS ratings under full and hungry conditions, respectively. This shows that energy load had a greater influence on PS ratings than either energy density or weight of test foods. Since energy load of the banana (76kcal) was smaller than the energy load of the cornflakes (235kcal), this may explain why the banana was perceived as less filling than the cornflakes, despite being slightly heavier and lower in energy density. It may also explain why the remaining foods in the study were perceived to be more filling than the banana, despite the fact that they were HED or MED. Sweet, high-fat snacks can be perceived as filling (Green and Blundell, 1996) and research shows they may be perceived as more filling than fruit, vegetables and grains (Oakes, 2006). This cannot be attributable to fibre and water content alone, which are associated with increased satiety (Kral and Rolls, 2004; Holt et al. 1995), since sweet, high-fat snacks are low in these components. However, due to their high energy density, sweet, high-fat snacks are high in energy load, especially in large portion sizes (Kral and Rolls, 2004; Ello-Martin et al. 2005). Therefore, in the present study, presenting foods with high and medium energy densities in large portion sizes may explain why PS ratings were higher in these foods than in the banana. The only exception seems to be for the cornflakes where PS ratings were higher than in the chocolate bar and the muffin. The energy load and the weight of the cornflakes was smaller than for the chocolate bar and the muffin, so it was logical to expect that the cornflakes would be less filling than both of these foods. However, the cornflakes were the only test food where weight and energy load did not reflect PS ratings, thus suggesting that expectations of fillingness were affected by factors other than weight and energy load. In contrast to the other test foods, the cornflakes were presented in a bowl, without any packaging. Research has shown that perception of portion size is affected by serving container and package size (Wansink, 2004; Wansink and Cheyney, 2008; Wansink et al.2006), so it is logical to expect that these factors may also influence PS. In addition, it is possible that subjects considered PS for the cornflakes in the presence of milk, since this is how cereal is normally served. Although milk is a liquid, research suggests that it is more satiating than other caloric beverages, possibly due to its protein content and viscosity (Rolls and Barnett, 2000; Harper, James, Flint and Astrup, 2007; Tsuchiya et al. 2006; Almiron-Roig et al. 2003).

## 4.7. The effects of familiarity and liking on PS ratings.

Contrary to data from Brunstrom et al. (2008b) results from the present study failed to demonstrate significant correlations between expectations of fillingness and familiarity of foods and drinks. This may have been due to variations in the foods used in each study, as well as a failure to include drinks in the study by Brunstrom et al. (2008b). However, it may also have been due to differences in the methods used to measure familiarity. Brunstrom et al. (2008b) measured familiarity according to frequency of consumption. Therefore, foods consumed more often were considered more familiar. In the present study however, familiarity was measured according to how familiar subjects were with the taste and feel of test foods/drinks in their mouths. Different methods of measurement would likely generate different results. For example, more filling foods may be consumed more often because they are more satisfying, and thus will be rated as more familiar.

In addition to variations in the methods used to measure familiarity, methods of measuring expected fillingness varied between the two studies. In the present study expectations of fillingness were based on perceived **satiation** (PS), whereas measures of fillingness in the study by Brunstrom et al. (2008b) were based on **satiety** expectations (ES). ES is a measure of whether or not a particular portion of food can stave off hunger until the next meal (Brunstrom and Shakeshaft, 2009); PS is a measure of how full a person expects to feel on finishing a certain amount of food (Irvine et al. 2008). Therefore, despite the fact that unpublished data suggests ES and PS are reasonably well correlated (Brunstrom and Shakeshaft, 2009) it is possible that assessing expectations of fillingness based on measures of satiation as opposed to satiety may have generated different results. Also, in the study by Brunstrom and et al. (2008b), expectations of fillingness were measured at different times of day, without controlling for variations in levels of hunger and fullness. Since the present study confirms that expectations of fillingness are affected by variations in appetite status, failure to control for appetite status in the study by Brunstrom et al. (2008b) likely affected measures of ES. In turn, this may have caused further variations in measures of expected fillingness between the two studies, which may partly explain the failure to detect a relationship between familiarity and PS in the present work.

Finally it is important to note that in the present study, PS was measured in test foods/drinks of different weights and energy loads, both of which were partly responsible for variations in PS ratings (see section 4.6). In contrast, Brunstrom et al. (2008b) measured ES in foods of similar weights. It is therefore possible that variations in weight and energy load may have masked the effects of familiarity on PS ratings in our study.

Ideal food portion size has been shown to increase with increases in liking (Brunstrom and Shakeshaft, 2009). Therefore, one could argue that as liking for a particular food increases, PS ratings for that food will decrease. The present study showed that there were no significant correlations between liking of test foods/drinks and PS ratings. However, this may be due to variations in weight and energy load of test foods/drinks, which may have masked the effects of liking on PS ratings. Also, the number of foods included in the study (n = 8) may have been too small to reveal a relationship between liking and PS ratings.

## 4.8. The effects of perceived satiation on portion size estimates and accuracy of estimation.

The results of the present study demonstrate that employing a PS cue prior to portion size estimation had no effect on portion size estimates or accuracy of estimation in any of the test foods/drinks. The second hypothesis, 'Considering PS prior to portion size estimation increases portion size estimates and accuracy of estimation, especially in foods with lower energy densities' could not be demonstrated.

There are several explanations as to why the PS cue had no effect on portion size estimates in any of the test foods/drinks, thus disputing the findings from Brunstrom and Shakeshaft (2009). Firstly, measuring PS in foods/drinks of different weights and energy loads likely affected PS ratings, perhaps distorting expectations of fillingness in foods/drinks and consequently masking any effects of PS on portion size estimation, particularly with respect to energy density (see section 4.6). Secondly, the study by Brunstrom and Shakeshaft (2009) measured expected satiety (ES), whilst the present study measured perceived satiation (PS). As mentioned previously, unpublished data suggests that satiation and satiety are reasonably well correlated (Brunstrom and Shakeshaft, 2009). However, the current study provides the first experimental evidence on the role of expected satiation in decisions about portion size under controlled appetite conditions (Brogden and Almiron-Roig, unpublished). Therefore, it is possible that, in contrast to ES, PS actually has no effect on portion size estimation. Perhaps the satiating capacity of foods required to stave off hunger until the next meal (ES) is considered more important than the satiating capacity of foods required for meal termination (PS). Also, despite showing that ES predicted prospective portion size, a closer inspection of the study by Brunstrom and Shakeshaft (2009) reveals several limitations which may have affected results. The study involved only 7 solid snack foods, whereas the present study included foods across a range of energy densities and also drinks. In addition, although participants in the study by Brunstrom and Shakeshaft (2009) were male and female, they failed to control for gender differences in their analyses. This was avoided in the present study by restricting recruits to male participants only. However, perhaps the most important difference between the present study and the work of Brunstrom and Shakeshaft (2009) is that Brunstrom and Shakeshaft (2009) measured ES and prospective portion size at different times of day, without controlling for variations in levels of hunger and fullness. Therefore, the study failed to assess how ES was affected by differences in appetite status. The present study shows that PS measures were significantly lower when subjects were hungry compared with when they were full, thus causing portion size estimates to be significantly smaller under hungry conditions. This confirms that appetite status must always be accounted for when designing interventions involving expectations of fillingness and its effects on portion size estimation.

Other factors which may have prevented the PS cue from affecting portion size estimates in the present study include exclusion of restrained eaters and restrictions on participant BMI. In the study by Brunstrom and Shakeshaft (2009), expected satiety was a greater predictor of portion size in restrained eaters and subjects with a higher BMI. The authors hypothesised that these individuals place greater weight on expectations of fillingness when making decisions about portion size (Brunstrom and Shakeshaft, 2009). However, the lack of effect seen with the PS cue may also have occurred as a result of the concept on which it is based. The ability of the PS cue to effect adjustments in portion size relies on two factors: (a) individuals reflecting on previous feelings of fillingness associated with each test food and (b) individuals using previous feelings of fillingness to modify portion sizes. Since expectations of fillingness vary according to the context in which foods have been eaten in the past (Brunstrom, 2008), assessing PS accurately based on a range of previous experiences would be extremely challenging. This may have resulted in participants estimating portion sizes based on amounts habitually consumed, rather than engaging in a more complex decision-making process (Brunstrom and Shakeshaft, 2009). In an attempt to encourage subjects to estimate portion sizes based on their immediate need, subjects were asked to consider PS and portion size for each food and drink ‘at this moment in time’. However, this does not guarantee that participants actually used PS as a basis for estimating portion sizes; nor does it guarantee that PS was assessed with any degree of accuracy. In a recent study by Ueland et al. (2009) variations in portion size information provided with the same amount of pasta preload had no effect on satiety post consumption or subsequent food intake. The authors concluded that participants did not use feelings of fillingness based on previous experiences to determine subsequent intake. Instead they relied on actual hunger, which is partly dictated by hormonal regulation of appetite, including strong signals from the orexigenic (hunger) hormone ghrelin (Cummings and Overduin, 2007). Results from the present study fully support these findings. The PS cue had no effect on portion size estimates. However, portion size estimates were adjusted according to appetitive sensations, i.e. hunger/fullness.

As discussed previously, results from the present study showed that the PS cue had no effect on portion size estimation or accuracy of estimation in any of the test foods/drinks employed in the study. However, it is important to point out that nested ANOVA showed a trend for portion estimates in the HED crisps to be smaller in the presence as opposed to the absence of PS cue, which is opposite to what was expected. This cannot be explained by the fact that HED foods are associated with lower expectations of fillingness (Brunstrom et al. 2008b) for several reasons. Firstly, in the present study between-foods comparisons showed that crisps were perceived to be more filling than any of the other tests/foods drinks in the study, except for the ice cream. In addition, PS was shown to increase with increasing energy density and PS had no effect on portion size estimation in any of the other HED foods. A more probable explanation for the crisps appearing smaller in the presence of the PS cue is that accuracy of portion size estimation was affected by the appearance of the test foods and drinks. A serving of crisps is made up of an unknown number of units which vary in shape and size, and are loosely packaged in an oversized bag. Therefore, it is likely that accurate estimation of a portion of crisps is more difficult than estimating the portion size of a food which is tightly packaged in a single or known quantity of equal sized units, or displayed in the absence of packaging, as for all other foods/drinks in the study (Rolls, 2003).

Previous research suggests that energy-containing beverages are less satiating than solid foods (Mattes and Campbell, 2009; Almiron-Roig et al. 2003; Popkin et al. 2006). Thus, although the PS cue was expected to increase beverage portion size estimates, the effect was expected to be smaller than the effect of PS on solid foods. Despite this, between foods comparisons showed that both drinks were perceived as more filling than the banana and the chocolate bar under full conditions; and more filling than the banana under hungry conditions. However, demonstrating the reasons for this are beyond the scope of this study. Drinks show variations in expectations of satiety based on differences in nutrient composition, viscosity and volume, as well as timing of ingestion, i.e. whether they are taken prior to or as part of a meal (Tsuchiya et al. 2006; Almiron-Roig and Drewnowski, 2003; Mattes, 2006; Almiron-Roig et al. 2003; Rolls et al. 2000; Flood et al. 2006). As a result, it is difficult to compare PS ratings in drinks with PS ratings in foods. Thus, further research is required to assess expectations of fillingness in caloric drinks compared with foods of varying energy densities.

### 4.9. The effects of energy density on accuracy of portion size estimates.

Accuracy of portion estimates tended to decrease with increasing energy density and the relationship was strengthened in the presence of drinks, as expected. These results support the third hypothesis, (portion sizes of HED foods and caloric drinks are estimated less accurately than portion sizes of foods lower in energy density) and are consistent with findings from Burger et al. (2007). However, in the present study, energy density was only responsible for 13% of the variance in percentage error values in the presence of drinks. Since research shows that accuracy of estimation decreases with increasing portion size (Rolls, 2003; Davis et al. 2006; Wansink, 2007) it was logical to assume that weight of test items may also have affected accuracy of estimates. Surprisingly, results showed no relationship between weight of test foods/drinks and percent error. However, in contrast, percent error of estimates was shown to increase with increasing energy load, which was responsible for 15% of the variance in percent error of estimates. Thus, the present study provides evidence for the first time that accuracy of portion estimates decreases with increasing energy load. Since energy load is a product of weight and energy density, this may help to explain why people perceive large portions of energy dense foods as appropriate amounts to consume on a single eating occasion; a phenomenon known as portion distortion (Schwartz and Byrd-Bredbenner, 2006).

Percent error values for each food and drink based on DOM UK standards showed that portion estimates were more accurate in foods of lower energy densities (banana and cornflakes) than in HED foods and drinks, as expected. The only exception occurred with the ice-cream (MED), which according to DOM UK was estimated with the least accuracy. However, this may have been due to energy load, which was higher in the ice-cream than in any of the other test foods/drinks.

With respect to FSA, ADA and FDA standards, such clear patterns of accuracy according to energy density were not evident, despite the fact that overall, percent error increased with increasing energy density. One explanation for this is that FSA, ADA and FDA standards are based on weight, whereas DOM UK standards are based on kilocalories and thus energy load. This resulted in actual portion sizes based on DOM UK standards being substantially larger in foods with higher energy loads (HED foods and the MED ice-cream), followed by drinks and finally foods of lower energy loads ((banana (LED) and cornflakes (MED)). This explains why the order of accuracy according to DOM UK standards appeared to be associated with energy density, when in fact it may have been associated with energy load. Except for the ice-cream, energy loads and thus actual portion sizes based on DOM UK standards were higher in HED foods and drinks compared with foods of lower energy densities. In turn, this made the difference between portion estimates and actual portion sizes appear greater in HED foods and drinks than in foods of lower energy densities.

### 4.10. The effects of liking and familiarity on portion size estimation.

In the study by Brunstrom and Shakeshaft (2009) results showed that as liking for test foods increased, so did ideal portion size. The effect was independent of, but equal in strength to the effect of ES on ideal portion size. Based on these findings it was logical to expect that, in the present study, portion estimates would decrease with increased liking, i.e. the more you like something, the more of it you could imagine eating and thus your perception of portion size would decrease. However, results from the present study appear to dispute the findings from

Brunstrom and Shakeshaft (2009). Between-foods comparisons showed no relationship between mean liking ratings and mean portion estimates. Despite significant differences between mean liking ratings, mean portion estimates tended to fall within a much smaller range (1 and 1.5). In addition, although mean liking ratings for the ice-cream tended to be higher than for the crisps (a relationship which almost reached significance) mean portion estimates for the ice-cream and the crisps were similar. This was also true for the chocolate bar and the cornflakes; despite an almost significant difference in mean liking ratings between the two foods, mean portion size estimates were comparable. However, in contrast to the previous results, correlations between individual liking ratings and individual portion size estimates for each food and drink, showed that as liking increased, portion estimates for the banana and cola decreased, as hypothesised. Also, based on individual comparisons, there was a tendency for portion estimates for the ice-cream to decrease with increased liking, as hypothesised. In contrast, portion estimates for the cornflakes increased with increased liking and there was a trend for a similar relationship in the hot-chocolate. There were no significant correlations between individual liking ratings and portion estimates for the chocolate bar, muffin or crisps. Therefore, results show that liking has a selective influence on portion size estimation.

The reason why the relationship between individual liking ratings and portion size estimates varied between foods may be explained by confounding variations in weight and energy load of test foods. Weight has been shown to affect PS ratings; energy load has been shown to affect PS ratings and percent error of estimates. Therefore, it is logical to expect that weight and energy load may also affect portion size estimation. In turn, this may have affected the relationship between liking and portion size estimates in each food and drink.

In the study by Brunstrom et al. (2008b) ES was shown to increase with familiarity of test foods. Therefore, one may expect that as familiarity increases so will estimation of portion size. However, in the present study, correlations between individual measures of familiarity and individual portion size estimates for each food and drink showed that as familiarity increased, portion estimates in the cola and the ice-cream actually decreased. For the remaining test foods/drinks, there were no significant correlations between familiarity and portion estimates. These results may be attributable to the fact that, in contrast to findings from Brunstrom et al. (2008b), the present study showed no relationship between expected fillingness (PS) and familiarity. The reasons for this are discussed in section 4.7 and may explain why portion size estimates did not increase with increased familiarity.

In conclusion, the present study suggests that people do not rely on food liking and familiarity when estimating portion sizes. Instead appetitive sensations i.e. hunger/fullness, act as more important predictors of food/drink portion size.

## 4.11. Limitations of this work and future research.

The present study revealed that portion size estimates for all foods/drinks were significantly larger when male subjects were full compared with when they were hungry. However, further research is required to determine if increased portion size perceptions actually lead to reductions in food intake. Previous studies have shown that even where people are aware they have been served foods in increasing portion sizes they do not adjust their intake accordingly (Ueland et al. 2009; Rolls et al, 2004a; Rolls et al. 2007; Kral, 2006). However, in situations where individuals are responsible for selecting their own portion sizes, it is possible that increased portion size perceptions may lead to reductions in amounts served and thus amounts consumed. Therefore, further work could be carried out to investigate if portion size estimation affects the size of food portions prepared, selected and consumed at home. Since food intake is affected by availability (Rolls, 2003) it is also important to assess the effects of portion size perception on the size of portions purchased during food shopping.

Results from the present study have shown that employing a PS cue has no effect on portion size estimation, irrespective of energy density. However, since measures of PS were affected by weight and energy load, the effect of energy density on PS requires further investigation. Since PS promotes meal termination (Cummings and Overduin, 2007) considering PS prior to consumption of HED foods may be particularly useful, as these foods are associated with passive over consumption and possible weight gain (Jebb, 2005; Kral et al. 2004; Rolls et al. 2006). Therefore, to investigate the effects of energy density and drinks on PS, PS should be measured in at least eight foods from each category of energy density (LED, MED and HED) and at least eight drinks. This would increase the possibility of detecting a relationship between PS and energy density, should one exist. Also, since the present study included males only, due to potential differences in expectations of fillingness according to gender (Brunstrom and Shakeshaft, 2009), any future studies investigating the relationship between PS and energy density should include both men and women. Ideally, foods/drinks should be presented in similar amounts and since portion size estimation is affected by food form (Weber et al. 1999) and container size (Wansink et al. 2006) future studies should control for these factors. When studying drinks, both caloric and non-caloric varieties presented in similar sized cups or glasses should be used. Since PS is affected by appetite status, this factor should also be controlled for when assessing expectations of fillingness. Finally, low liking and familiarity cut off points used in the recruitment process for this study (see section 2.2) resulted in increased variability amongst participants. This may have affected portion size estimates, due to difficulties experienced by participants when imagining feelings associated with consumption of unliked or unfamiliar foods. As a result, future studies on the relationship between PS and energy density should exclude subjects with liking and familiarity scores of ≤50 (Raudenbush and Frank, 1999).

Once measures of PS have been collected in an increased number of foods and drinks under controlled conditions as described, participants could be asked to estimate portion sizes of the same foods and drinks under similar conditions. The results from both studies could be used to re-assess the relationship between PS and estimation of portion sizes. In addition, portion size estimates could be used to further investigate how energy density affects accuracy of portion size estimation. Finally, data analyses could be carried out to determine if caloric content of drinks affects accuracy of beverage portion size estimation and how accuracy of estimates in foods compares with accuracy of estimates in drinks.

### 4.12. Implications for professional practice.

The present study demonstrates that males tend to significantly underestimate food/drink portion sizes; and that underestimation is more pronounced under hungry conditions, in HED foods and caloric drinks. Since underestimation may lead to portion distortion and thus excess energy intake (Schwartz and Byrd-Bredbenner, 2006; de Graaf, 2006, Burger et al. 2007) devising strategies to improve estimation of food/drink portion sizes is essential. Results from the present work indicate that portion size estimates increase when people are full, which in turn leads to more accurate estimation of food/drink portion sizes. Therefore, to decrease selection and consumption of foods/drinks in excessive amounts, it seems reasonable to recommend that meal preparation and food shopping is carried out when people are full. This advice may be particularly useful for individuals who are trying to lose or maintain their weight. Indeed, scientific speculation and anecdotal accounts have long suggested that hungry supermarket shoppers purchase relatively greater quantities of food (Brunstrom et al. 2008a). In addition to preparing and purchasing foods when full, consumers could also be advised to divide large portions of food into smaller portions when sated. This could lead to foods being separated into smaller portions than foods apportioned when hungry, and in turn may prevent consumption of excessive portion sizes.

Despite more accurate estimation of portion sizes under full conditions, the present study showed significant discrepancies between portion size estimates and actual portion sizes based on health professional and government standards, irrespective of appetite status. This suggests a need to educate the general public on what constitutes appropriate portion sizes of different foods and drinks. In order to achieve this, a single guidance scheme providing consistent information on suitable portion sizes must be developed (Hackett, 2009). Standards should be based on recommended amounts, rather than amounts customarily consumed per eating occasion. Indeed, the present study shows that standards which reflect customary intake disguise the magnitude of inaccuracies associated with portion estimates and provide an invalid picture of the direction in which inaccuracies occur. Therefore, standards based on recommended amounts, such as those provided by the health professional bodies are likely to be better indicators of appropriate portion sizes. Unfortunately, since DOM UK was created to achieve weight loss in overweight/obese patients, it is both unavailable and unsuitable for use by the general public. This is also true of the ADA scheme, which was produced for dietary management of diabetes. Therefore, a simpler scheme is required to educate the general public on what constitutes appropriate portion sizes of different foods and drinks, and to highlight discrepancies between recommended portion sizes and those which are available in restaurants and supermarkets. This scheme should provide specific, objective information on portion sizes (e.g. in gram weights) (Ueland et al. 2009) which is easy to understand, as opposed to current health professional schemes which use household measures (ADA) and kilocalories (DOM UK) to define a portion size.