Estimating everyday portion size using a 'method of constant stimuli': In a student sample, portion size is predicted by gender, dietary behaviour, and hunger, but not BMI.

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ABSTRACT

This paper i) explores the proposition that body weight is associated with large portion sizes and ii) introduces a new technique for measuring everyday portion size. In our paradigm, the participant is shown a picture of a food portion and is asked to indicate whether it is larger or smaller than their usual portion. After responding to a range of different portions an estimate of everyday portion size is calculated using probit analysis. Importantly, this estimate is likely to be robust because it is based on many responses. First-year undergraduate students (*N*= 151) completed our procedure for 12 commonly consumed foods. As expected, portion sizes were predicted by gender and by a measure of dieting and dietary restraint. Furthermore, consistent with reports of hungry supermarket shoppers, portion-size estimates tended to be higher in hungry individuals. However, we found no evidence for a relationship between BMI and portion size in any of the test foods. We consider reasons why this finding should be anticipated. In particular, we suggest that the difference in total energy expenditure of individuals with a higher and lower BMI is too small to be detected as a concomitant difference in portion size (at least in our sample).

KEYWORDS: Portion size hunger psychophysics BMI method of constant stimuli dietary restraint dieting probit analysis energy expenditure

INTRODUCTION

A number of studies indicate that a positive relationship exists between the size of an available meal and the amount of food consumed (Kral, 2006; Kral & Rolls, 2004; Rolls, Roe, & Meengs, 2004, 2006) . Moreover, this effect of meal size appears to be sustained over 11 days (Rolls, Roe, & Meengs, 2007), suggesting that larger portion servings promote a positive energy balance that results in an increase in body weight (Rolls, Roe, & Meengs, 2007).

On face value, the prospect that BMI and portion size are related would seem highly plausible. However, only a few studies report evidence that is consistent with this idea. (Note that we are drawing a distinction between portion size and energy intake). In a large cohort of American children, body weight and portion size were found to be positively correlated (Huang, Howarth, Lin, Roberts, & McCrory, 2004). Similarly, in Dutch adults, obese individuals (N= 34) reported consuming larger portions of high-energy foods than did non-obese age-matched controls (Westerterp-Plantenga, Pasman, Yedema, & Wijckmans-Duijsens, 1996). Notwithstanding these findings, relatively little is known about the relationship between perceived portion size and BMI in non-clinical adult populations. Recently, Burger *et al.*, explored the relationship between portion size and BMI in university students (Burger, Kern, & Coleman, 2007). In their study the participants were asked to serve themselves a typical portion of 15 different foods. After controlling for other potentially important variables, they found that the BMI positively predicted selected portion size in 10 out of the 15 foods. This result is potentially important, because weight gain appears to occur particularly rapidly in student populations (Levitsky, Halbmaier, & Mrdjenovic, 2004).

In this paper we introduce a novel approach to the measurement of portion size. Previously, portion-size estimates have been derived from food-frequency questionnaires in which participants select between categories such as “small,” “medium,” and “large” (Schlundt *et al.*, 2007; Tucker *et al.*, 2005). This approach is easy to implement. However, it may be subject to bias and error, relative to measures that rely on weighing of actual food (Robinson, Morritz, McGuiness, & Hackett, 1997). Asking participants to select real food portions (that are subsequently weighed) (*e.g.*, Burger *et al.*, 2007) is potentially more accurate. However, this approach is also costly and time consuming. In an attempt to address these problems we developed a methodology that uses an adapted version of a ‘method of constant stimuli.’ In a ‘classical’ (non adapted) version of this technique, the participants are shown a picture of a food portion on a computer screen. The portion size changes over a series of trials and the participant is asked to indicate whether the portion is larger or smaller than their normal portion size. After a sufficient number of trials, it is possible to plot the probability that a portion will be larger or smaller than their usual portion size. Probit analysis can then be used to fit a sigmoid function from which a ‘point of subjective equality’ can be derived. The point of subjective equality represents the point at which the ‘too much’ and ‘too little’ are selected 50% of the time. In this way, a measure of the ‘typical’ everyday portion is extracted. Figure 1 shows some hypothetical data and associated analyses.

<<< Insert figure 1 here >>>

This psychophysical approach is commonplace in most areas of sensory psychology and it has been used previously to compare the satiety that is expected after consuming a range of familiar foods (Brunstrom, Shakeshaft, & Scott-Samuel, submitted). However, it is also used in a wide variety of other contexts, such as deriving estimates of perceived body size (Fonagy & Benster, 1990) and to determine differences in ability to detect heartbeat sensations (Knapp-Kline & Kline, 2005; Schneider, Ring, & Katkin, 1998). The main advantage of the method of constant stimuli is that estimates are derived from a large number of trials. Thus, accuracy is thought to be greatly improved relative to approaches that rely on a single decision, such as food weighing or techniques involving the selection of an appropriate portion size from a set of photographs (Nelson, Atkinson, & Darbyshire, 1994). A second potential advantage is that participants are not required to identify their usual portion size explicitly. Consequently, this approach may be less subject to systematic under-reporting of portion sizes.

In Burger *et al.*'s study the test foods were primarily snack foods and spreads. Only two 'main meal' dishes were assessed; rice and macaroni and cheese. In the present study we sought to compare the relationship between BMI and a range of foods, including both snack and multiple-item main meals. In addition, an important aim of this study was to validate our psychophysical approach by making predictions about portion size based on specific participant characteristics. *A priori*, we predicted that males would indicate consuming larger portion sizes than females and that dieters and restrained eaters would indicate consuming relatively smaller portion sizes.

Finally, to our knowledge, researchers have not considered whether estimates of everyday portion size are influenced by hunger levels at the time at which judgements are made. Recently, it has been demonstrated that hungry participants experience a relatively poorer ability to discriminate between foods based on expectations about the satiety they are likely to deliver (Brunstrom *et al.*, submitted). To explore whether hunger influences other judgements relating to portion size we also included a measure of hunger in this study.

METHODS

Participants

One hundred and fifty-one first year Swansea University students (88 female, 63 male) were recruited to take part in this research. The average age of the participants was 18.7 years (standard deviation = 0.78). All confirmed that they were living in shared student accommodation, that they were native English speakers, and that they were not colour-blind. All participants received 10 pounds Sterling for their assistance.

Measurement of portion size

Perceived portion size was measured using a procedure adapted from Brunstrom *et al.* (Brunstrom, Shakeshaft, & Scott-Samuel, submitted). Measures of typical portion size were calculated for 12 foods. We chose foods that that are commonplace in the UK and that are typically regarded as either a complete main meal, a side dish, or a snack (or luxury) food. Each category comprised four foods (main meal - chicken tikka masala, 'eggs, chips, and beans,' lasagne, and 'pasta and tomato sauce'; side dish - rice, sweet corn, potatoes, and peas; snack food - chocolate, crisps, peanuts, and cake).

For each participant, a separate point of subjective equality was computed for each food. Each point of subjective equality was derived from 56 trials. During each trial, a photograph of the food was presented in the middle of a 19 inch VDU. Participants were instructed to "Think about whether you would typically eat a larger or smaller portion than that presented. When making your decision you should imagine a typical situation where you are free to select the food and determine the portion size you would like to eat." On occasions when the portion size was smaller than their normal portion they were instructed to press the left arrow key. When it was larger than their normal portion they pressed the right arrow key. At the outset, participants were informed that there are three different categories of food; main meals, side dishes, and snacks.

The classical method of constant stimuli is highly inefficient. Much of the psychophysical function comprises responses that are trivial because the participant consistently chooses either ‘too much’ or ‘too little’ (for example, see extreme end points of the function in Figure 1). To greatly improve the efficiency of our procedure we chose to use the Adaptive Probit Estimation algorithm (Watt & Andrews, 1981). With this approach, only a subset of the comparison range is tested. Each set of 56 trials is divided into 7 sub-sessions, each comprising 8 trials. In each sub-session, four different stimulus values are used. At the end of the second and every subsequent block, a rapid and slightly approximate probit analysis is made. On the basis of this analysis, four stimulus levels are reselected as necessary. In each case, stimulus levels are selected that maximise the prospect of gaining information about the point of subjective equality. In practice, this means that values are chosen from a wide range of comparisons at the beginning of the session. Over successive sub-sessions, the range of values becomes increasingly smaller and their average value tends to correspond ever more closely with a participant’s perceived portion size.

Each participant completed a single block of 12 trials that contributed towards the 12 psychophysical functions described above. A single trial relating to each of these 12 foods was presented in turn (a block), and this process was then repeated a further 55 times (12 trials x 56 blocks = 672 trials). This task took approximately 15 minutes to complete. During this period the participants were invited to take a break after completing half of the trials.

The Adaptive Probit Estimation routine and the code for presenting the stimuli were both written in Matlab (version 6). The graphical interface was implemented using Cogent Graphics software (freeware).

Food picture stimuli and associated comparison ranges

The test foods were arranged on a 255-mm diameter white plate and high-quality digital images were obtained using a digital camera that was mounted directly overhead. Particular care was taken to ensure identical lighting and arrangement on the plate across foods and portion sizes.

In total, 41 images were taken of each food. For each food, picture 21 represented a typical average portion size. These values were taken either from packaging information or from Gregory, Foster, Tyler, and Wiseman (1990). In the case of the main meals, picture number 1 and picture number 41 depicted ⅓ and 3 times the weight of the average portion, respectively. Pictures between 1 and 41 showed portion sizes that were equally spaced in log units. The snack foods and side dishes were photographed in the same way, but with a range spanning 0.25 and 4 times that of the average portion. Our decision to use two slightly different scales reflected constraints on the amount of food that could be physically presented on the plate.

The macronutrient composition of the 12 test foods was taken from food packaging and is provided in Table 1. Separate values are given for the component parts of the main meals. Table 1 also includes the weight of the average portion sizes.

<<< Insert Table 1 here >>>

Other measures

Measures familiarity and liking: For each test food we obtained a measure of liking using a seven-point semantic differential scale. End points on this scale were labelled “unpleasant” and “pleasant.” Familiarity was assessed using a questionnaire. Specifically, participants were asked how often they consumed each food. For each food they selected from “never,” “less than once per year,” “once a year,” “monthly,” and “every week.” Respectively, these responses were coded numerically 1 to 5.

Measures of hunger and everyday dietary behaviour: Participants were asked to indicate whether they were actively dieting in order to lose weight. They then completed the dietary restraint section of the Dutch Eating Behaviour Questionnaire (van Strien, Frijters, Vanstaveren, Defares, & Deurenberg, 1986) and a 100-mm visual-analogue rating scale with the title “How hungry are you right now?”; the end anchor points were labelled as ‘not hungry at all’ and ‘extremely hungry.’

Procedure

Participants arrived at the laboratory individually and were told that they were about to participate in a study that was going to explore their preoccupation with food and eating behaviour. They were also told that they would be asked questions about their everyday food portion sizes, and that a measure of their height and weight would be taken.

Initially, participants completed a set of tasks that assessed attentional bias to food and non-food stimuli (findings from this data set are reported elsewhere). After a 10-minute break, the participants were given the portion-size task to complete. This was followed by a measure of BMI. Finally, the participants completed the measures of hunger and everyday dietary behaviour.

Data analysis

On a number of occasions the Adaptive Probit Estimation algorithm was unable to select appropriate portions from which a point of subjective equality might be calculated. For the most part, this was because respondents consistently selected a portion size that was smaller than the size that was displayed. Inspection of the raw data suggests that in most cases the participants either did not like the food that was presented or may have been restricting their intake of that food. In these cases, the value for a point of subjective equality was entered as missing data. The number of missing data points differed across foods (between 4.1% and 20.2%, mean = 10.8%).

A separate regression analysis was used to explore the variance in typical portion size across each food. In each of the 12 analyses we included the terms gender, dieting status, dietary restraint, hunger, and BMI. In addition, to control for the effects of pleasantness and previous experience we also included our measures of food familiarity and liking.

Results

Participant characteristics

Table 2 shows the mean (SD) age, BMI, and restraint score associated with our sample of participants. Values are also provided for males and females separately. BMI was significantly correlated with dietary restraint in males (r= .41, p= .001) but not in females (r= .13, p= .21).

<<< Insert Table 2 here >>>

Predictors of typical portion size

Table 3 shows the results of our multiple regression analyses. Separate columns provide statistics associated with the five predictors: gender, dieting status, dietary restraint, BMI, and hunger. In each case the results are clustered by food type (main meal, side dish, or snack).

<<< Insert Table 3 here >>>

Males reported consuming significantly larger portions of six of the 12 test foods. No significant differences were found in the size of snack foods. Instead, reliable effects of gender tended to be found in our analyses of main meals and side dishes. Individuals who were either dieters, or who tended to restrict their dietary intake, indicated that they consumed significantly smaller portions in six of the foods tested. Dieters reported consuming significantly smaller portions of pasta and sauce (two other main meal portion sizes approached significance) and also smaller portions of three of the four snack foods tested (chocolate buttons, crisps, and cake). Dietary restraint predicted significantly smaller portions of two types of main meal, tikka massala and beef lasagne.

BMI failed to predict the portion size of any of the test foods (*p* values in the range .20 - .99), except for rice. In the case of rice, we found a negative relationship with BMI. That is, individuals with a lower BMI tended to report consuming a larger portion size. Finally, we found evidence that reports of everyday portion size are influenced by hunger at the time of test. In nine out of the 12 foods we found that hungry participants indicated consuming a significantly larger portion of that food.

DISCUSSION

The main aim of this study was to determine whether portion-size estimations can be obtained using a method of constant stimuli. In this respect, the study appears to have been successful. Participants reported no difficulty in responding in the task and appeared to understand the instructions they were given. To test our approach we made two predictions from the outset. Firstly, we predicted that males would indicate consuming larger portion sizes than females. Secondly, we predicted and that restrained eaters and dieters would report consuming smaller portions than unrestrained eaters and non-dieters. Both of these predictions were supported by the data.

In relation to the effect of gender, we found differences primarily with respect to side dishes and main meals. By contrast, differences between dieters and non-dieters and between high- and low-restrained eaters were found in snack foods and main-meal portion sizes. One explanation is that these snack foods and main meals are more likely to be restricted because they are perceived to be more energy dense. This hypothesis remains to be tested and further research is needed to understand the social and psychological variables that determine why certain foods are apparently restricted while others are not. The present methodology may well be a useful tool in research of this kind.

An important finding from this work is the absence of a positive relationship between BMI and portion size. We did find that BMI was a significant predictor of rice portion size. However, in this case higher BMI was associated with the consumption of smaller portions. In all of the other test foods BMI failed to approach significance as a predictor of portion size. Thus, contrary to a recent report (Burger, Kern, & Coleman, 2007), we found no evidence that a positive relationship exists between everyday portion size and BMI.

A general problem with research of this kind is that participants can misreport the amount of food that they consume. Some studies suggest overestimation occurs while others find underestimation (Barrett-Connor, 1991). More importantly, over or underreporting may take place in particular sub groups. Contrary to expectation, overestimation of intake has been reported in overweight individuals (Lansky & Brownell, 1982). However, rather more studies report underestimation in this group (Okubo & Sasaki, 2004; Prentice et al., 1986). The most likely reason for this is that these individuals have particular concerns about the negative impression that truthful responding is likely to give (Hebert, Clemow, Pbert, Ockene, & Ockene, 1995). One possibility is that the same underreporting accounts for the lack of association between BMI and portion size in our study. More data are needed to resolve this issue. However, there are aspects of the results and method of data collection that make this prospect less likely. Firstly, we would expect underreporting to occur primarily in restrained eaters and dieters. This is because these participants are more likely to have concerns about the consequences of consuming larger portions. However, in our analyses we entered BMI, dietary restraint, and dieting status simultaneously as predictors of portion size. Therefore, it would appear that the conspicuous lack of relationship between BMI and portion size is evident even after controlling for underreporting that might be evident in individuals who may have concerns about consuming large portion sizes.

Second, the evidence that obese individuals underreport comes primarily from reports of *energy* intake over a fixed period of time (*e.g.*, 24 hours). It remains to be determined whether underreporting also takes place when participants estimate their typical everyday *portion size*.

Indeed, one possibility is that portion sizes are similar in overweight and lean individuals. Instead, differences in daily energy intake should otherwise be attributed to the number of meals or snacks that these groups typically consume (Ma *et al*., 2003). In future this possibility might be explored by incorporating an assessment of meal frequency and meal variability. Finally, in our methodology estimates of portion size are derived from a probability function based on two-interval binary-choice responses. Therefore, underreporting is perhaps less likely to occur because participants are never required to explicitly identify typical portion sizes. Again, further research is needed to confirm the extent to which this is the case.

In relation to our failure to observe a relationship between BMI and portion size, we feel that it is also worth commenting on the size of the association that might be expected. In an extensive analysis of 574 doubly labelled water measurements, Black *et al.* were able to derive a regression model that predicts the total energy expenditure of individuals in affluent societies as a function of their body weight, height, age, and gender (Black, Coward, Cole, & Prentice, 1996). Using this model, we predicted the energy expenditure for each of the participants tested. We then divided our sample based on a median split of their BMI values and calculated the average estimated energy expenditure for the high- and low-BMI group separately. Those in the low-BMI group had an average BMI of 20.7 and an estimated daily energy expenditure of 11.75 MJ. Those in the high-BMI group had an average BMI of 26.1 and an estimated daily energy expenditure of 12.05 MJ. If we assume neutral energy balance and similar meal frequency in both groups, then we suspect that this margin (2.55%) is too small to be detected as a concomitant difference in portion size, using our methodology, or indeed any other. Of course, this does not mean that a reliable relationship between BMI and portion size would not be observed across a larger BMI range (indeed we would anticipate this to be the case). Furthermore, we are not suggesting that the modest difference in predicted expected energy expenditure necessarily means that high- and low-BMI groups will consume similar portion sizes, merely that we found no evidence to the contrary. Clearly, decisions about portion sizes will be driven by a number of factors (not just energy expenditure). Some participants may be in positive or negative energy balance, and in this regard we suspect that recent dieting history might be particularly important. Although we measured current dieting behaviour, some of our participants may have recently given up dieting while others may have recently entered into a determined effort to lose weight. These different dieting strategies might explain a considerable degree of the variance in portion size estimations. Accordingly, measures that target these specific behaviours should be incorporated in future studies.

Finally, in this study we were also interested in the extent to which measures of average portion size are influenced by hunger at the time of testing. Analysis of hunger ratings yielded a surprising and highly robust relationship – hungry participants indicated consuming significantly larger portions of food. To our knowledge this is the first study to report a relationship of this kind. The underlying process remains to be explored. However, it would seem that hunger somehow colours or distorts memories or reporting of food portions consumed in the past. One possibility is that this effect links with scientific speculation (Dodd, Stalling, & Bedell, 1977; Mela, Aaron, & Gatenby, 1996), and with anecdotal accounts, that hungry supermarket shoppers purchase relatively greater quantities of food. Either way, a clear recommendation from this work is that hunger should be considered in any future assessments of everyday portion size.

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Figure captions

Figure 1: The point of subjective equality relates to the point at which a given portion is likely to be chosen as too large (or too small) 50% of the time.

Tables

Table 1. Macronutrient composition (grams) of the 12 test foods (values given per 100 g), together with the weight of the 'average portion size' associated with each food. Separate values are provided for each component of the main meals. Common numbers (in parentheses) indicate that the component contributed to the same meal.

Food and food type	Carb (g)	Protein (g)	Fat (g)	Fibre (g)	Total energy (Kcals/100 g)	Weight of average portion (g)
Snack foods						
Chocolate buttons	56.7	7.7	29.9	0.7	525	32
Crisps (potato chips)	49	6.5	34	4.0	530	25
Peanuts	9.9	27.5	49.0	9.0	590	50
Cake	58.4	3.8	17.3	1.0	405	76
Side dishes						
Sweet corn	19.6	4.2	2.3	2.2	116	68
Peas	9.1	6.0	0.9	5.1	69	69
Rice	30.0	3.2	1.7	0.5	148	175

New potatoes	17.8	1.5	0.3	1.1	321	177
Main meals						
(1) Pasta	73.1	12.3	1.7	2.5	357	219
(1) Tomato Sauce	9.2	1.3	1.2	0.8	53	125
(2) Chicken Tikka Masala with rice (packaged together)	16.6	7.1	10.0	1.7	181	453
(3) Beef Lasagne	12.0	6.0	3.0	0.6	100	300
(4) Scrambled Egg	5.0	15.9	12.0	<0.1	196	116
(4) Chips	28.0	3.4	4.9	2.5	170	163
(4) Beans	12.9	4.6	0.2	3.7	72	137

Table 2. Mean (SD) age (years), BMI (Kg/ m^2), and restraint score of the full sample and for males and females separately.

	N	Age	BMI	Restraint
Males	63	18.7 (0.7)	23.2 (3.0)	2.0 (0.7)
Females	88	18.7 (0.8)	23.6 (4.5)	2.7 (0.9)
Total	151	18.7 (0.8)	23.4 (3.9)	2.4 (0.9)

Table 3. Statistics associated with the five predictors of portion size. Separate values are given from the 12 regression models that were calculated (one for each food tested). Statistically significant *p* values ($p < 0.05$) are highlighted in boldface. Regression models included 'liking' and 'familiarity' as controlling variables. Note that the BMI predicts significantly *smaller* rice portion sizes.

Food	Gender				Dieting				Dietary restraint				BMI				Hunger			
	t	*SE*	*β*	*p*	*t*	*SE*	*β*	*p*	*t*	*SE*	*β*	*p*	*t*	*SE*	*β*	*p*	*t*	*SE*	*β*	*p*
Snack foods																				
Chocolate buttons	.66	1.4	.90	.509	-2.1	1.9	-4.1	**.035**	-1.9	0.8	-1.4	.060	-1.3	.18	-.23	.202	2.4	.28	.66	**.019**
Crisps (potato chips)	.70	1.4	.97	.483	-2.0	2.0	-3.9	**.049**	.75	.78	.59	.455	.14	.17	.02	.891	2.5	.29	.70	**.016**
Peanuts	1.1	1.4	1.4	.292	-1.3	2.1	-2.6	.211	-1.2	.74	-.87	.238	1.1	.18	.19	.286	3.1	.27	.85	**.003**
Cake	-.65	1.2	-0.8	.520	-3.1	1.7	-5.3	**.002**	-1.1	.66	-.76	.255	.52	.15	.08	.603	3.0	.25	.75	**.003**
Side dishes																				
Sweet corn	1.1	1.4	1.4	.288	-1.1	1.9	-2.1	.282	-.54	.74	-.40	.592	1.1	.18	.20	.280	.83	.28	.23	.410
Peas	2.3	1.0	2.4	**.022**	-1.8	1.5	-2.7	.081	-.65	.57	-.37	.516	-.75	.13	-.10	.457	1.2	.21	.25	.245
Rice	4.0	1.1	4.4	**.000**	-1.2	1.6	-1.8	.248	-1.2	.61	-.75	.219	-2.4	.15	-.36	**.018**	2.5	.23	.57	**.013**
New potatoes	2.9	0.9	2.7	**.004**	-1.4	1.4	-1.9	.163	.23	.51	.12	.822	.33	.13	.04	.741	1.8	.20	.34	.083
Main meals																				
Tikka masala & rice	2.9	1.0	2.8	**.004**	-1.6	1.4	-2.3	.103	-3.4	.52	-1.8	**.001**	.00	.12	.00	.998	2.9	0.2	.60	**.004**
Pasta & sauce	4.4	1.2	5.2	**.000**	-2.0	1.7	-3.3	**.050**	-.05	.64	-.03	.964	.90	.14	.13	.367	2.4	.24	.56	**.019**
Beef lasagne	3.3	1.4	4.6	**.001**	-1.6	2.1	-3.4	.110	-2.0	.78	-1.5	**.049**	.35	.18	.06	.725	2.1	.29	.59	**.041**
Egg, chips, & beans	1.8	1.0	1.7	.074	-.15	1.4	-.20	.880	-1.9	.51	-.99	.056	-.64	.12	-.08	.523	2.4	.20	.47	**.018**