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Research report

Perceived volume, expected satiation, and the energy content of self-selected meals☆

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ABSTRACT

Self-selected meals tend to be consumed in their entirety. Nevertheless, relatively little is known about the cognition associated with meal planning. Previously, we have shown that expected satiation is an excellent predictor of the energy content of self-selected meals. In the present study we sought to quantify the extent to which this relationship is mediated by differences in the perceived volume of foods (compared calorie-for-calorie). Testing took place at lunchtime. For nine highly familiar foods, participants ($N = 60$) selected a momentary 'ideal' portion, and then completed separate assessments of their expected satiation and perceived volume. Regression analysis revealed that expected satiation explained 74.8% of the variance in the energy content of self-selected meals (kcal) ($p < 0.004$). Of this, only 31% was shared with perceived volume, indicating that volume influences portion-size decisions by moderating expectations around satiation. However, a larger proportion of the variance (43.8%) can be considered 'unique' and independent of the perceived physical dimensions of the foods. We suspect that this contribution reflects the effect of prior learning, based on actual satiation that has been experienced in the past.

Introduction

Meals tend to be consumed in their entirety (Krassner, Brownell, & Stunkard, 1979; Lebow, Chipperfield, & Magnusson, 1985; Wansink & Cheney, 2005). Therefore, a critical determinant of energy intake is the cognitive activity associated with meal-size selection, before a meal begins (Brunstrom, 2007). Despite the significance of these decisions, relatively little is known about the basis on which they are made. This study considers determinants of the energetic content of self-selected meals.

Previously, Brunstrom et al. have quantified (calorie for calorie) the satiation (fullness) and satiety (relief from hunger) that participants anticipate from a range of commonly consumed foods (Brunstrom & Shakeshaft, 2009; Brunstrom, Shakeshaft, & Scott-Samuel, 2008). Foods differ considerably in this regard (up to a 5–6-fold difference). Defining and measuring expectations in this way leads to some striking and provocative findings. For example, these expectations are a very good predictor of the energetic content of self-selected portions (Brunstrom & Rogers, 2009; Brunstrom & Shakeshaft, 2009). By contrast, and contrary to the prevailing view, 'expected liking' for 16 commonly consumed foods explained less than 1% of the variance in self-selected portions (kcal) at lunchtime (Brunstrom & Rogers, 2009).

Expected satiety appears to increase as a food becomes familiar (Brunstrom et al., 2008). Presumably, these shifts in expectations can be attributed to an association that develops between the taste characteristics of a food and the post-ingestive events that occur after it has been consumed. This 'flavour-nutrient learning' explains why expectations are highly correlated with predictions of the 'actual' satiety that a food confers (Brunstrom et al., 2008) and it accounts for the finding that expectations can be learned under laboratory conditions (Wilkinson & Brunstrom, 2009).

In addition to effects of prior experience, judgments might also be influenced by other general or 'unlearned' food characteristics. In this paper we focus on the role of 'perceived volume.' Our interest in this topic stems from a number of studies exploring determinants of satiation and meal size. Consistently, researchers find that energy intake is reduced when low energy-dense foods are consumed (Bell, Castellanos, Pelkman, Thorwart, & Rolls, 1998; Fisher, Liu, Birch, & Rolls, 2007; Leahy, Birch, Fisher, & Rolls, 2008; Rolls, Roe, & Meengs, 2006; Stubbs, Johnstone, O'Reilly, Barton, & Reid, 1998). In a typical study the energy density of a test food is manipulated covertly. When participants are offered free access to a low energy-dense version they fail to fully compensate for this difference. Instead, they tend to consume a similar volume of food irrespective of its energy density (Bell, Roe, & Rolls, 2003). This observation is important because it suggests that satiation is

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Table 1
Macronutrient composition, frequency of consumption (mean and *SD*), and ideal self-select portion size (mean and *SD*), for each test food separately.

Food type	Carb[a] (g)	Protein[a] (g)	Fat[a] (g)	Total weight[a] (g)	Frequency per year		Ideal portion (kcal)	
					Mean	*SD*	Mean	*SD*
Pasta and sauce	14.0	3.5	3.5	65.5	107.5	78.2	465.0	139.2
Fish finger	8.5	7.0	4.0	54.0	16.0	22.7	407.7	164.9
Potato salad	7.4	0.8	7.5	70.9	13.8	20.1	474.7	235.9
Chowmein	8.7	7.0	4.2	122.0	31.2	32.9	302.3	145.2
Tikka masala	11.0	5.5	4.0	59.5	35.3	35.1	430.7	144.5
Oven fries	17.0	1.6	2.9	58.1	78.0	52.7	839.3	296.0
Steak	0.0	15.0	4.5	57.0	32.5	41.5	423.0	147.9
Baguette	8.8	4.9	5.1	31.4	66.1	75.8	560.0	151.2
Garlic bread	12.0	2.0	4.5	25.0	31.7	28.0	519.3	182.5

[a] Values given per 100 kcal.

determined by the volume of food that is consumed rather than by its energy content or macronutrient composition.

Based on the above, we hypothesised that the effect of volume on satiation might be anticipated and reflected in decisions about portion size, before a meal begins. To explore this prospect we used a psychophysical procedure to elicit separate volume and expected satiation judgments for several different foods. Using these responses, we sought to quantify the correspondence between expected satiation and perceived volume. In addition, we assessed the extent to which expected satiation and perceived volume account for measures of self-selected 'ideal portion size' (kcal). In this context, the role of perceived volume was explored using a 'variance partitioning procedure' (Chuah & Maybery, 1999). The extent to which expected satiation and perceived volume predict portion-selection can be explored separately. However, when their contribution is considered in combination, we expect to find a 'shared' component of the variance associated with each type of judgment. After accounting for this shared component we can calculate the 'unique' contribution of expected satiation and the unique contribution of perceived volume. By comparing the proportion of variance that is explained by unique and shared contributions we sought to elucidate the respective roles of expected satiation and perceived volume in decisions about portion size. *A priori*, we made three assumptions. Firstly, if decisions about portion size are based on an anticipation of the effects of physical volume on satiation then we would see a large shared contribution and a negligible unique contribution from expected satiation. Secondly, a large unique contribution from expected satiation and a small shared component would indicate that perceived volume plays a relatively minor role. Thirdly, differences in the perceived volume of foods (compared calorie for calorie) might influence judgments about ideal portion size (kcal), but in ways that are not accounted for by effects on expected satiation. This possibility would be confirmed by a large unique contribution from physical volume.

Methods

Participant characteristics

Participants were 60 undergraduate psychology students from the University of Bristol (UK), of whom 40 were female. Our sample had a mean age of 19.7 years ($SD = 0.7$) and a mean BMI of 21.9 ($SD = 2.5$). Participants completed the study as part of an undergraduate course requirement. Vegetarians and vegans were excluded. Ethical approval was obtained from the local Faculty of Science Human Research Ethics Committee.

Stimuli

Our primary objective was to explore effects of perceived volume in decisions about highly familiar foods. Based on previous studies we selected nine test foods that we suspected would be frequently consumed by our participants; pasta and tomato sauce, lean beefsteak, garlic bread, chicken tikka masala (rice and chicken with sauce), fish fingers (breaded fish), chowmein, potato salad, white roll baguette and cheese, and potato chips (fries). The macronutrient composition of these foods is provided in Table 1.

A set of photographs of the foods was taken using a high-resolution digital camera. Each food was photographed on the same white plate (255-mm diameter). Particular care was taken to maintain a constant lighting condition and viewing angle in all photographs. For each food, picture number 1 showed a 20 kcal portion. With increasing picture number the portion shown increased by 20 kcal (*i.e.*, picture 2 = 40 kcal, picture 3 = 60 kcal, and so on). In total, each food was photographed 40 times (maximum portion 800 kcal). The name of the food and (where appropriate) particular brand information was included in one corner of the images.

Measures

Ideal portion size: Ideal portion size was assessed over a series of trials. In each trial one of the test foods was displayed (size = 210 mm × 285 mm) in the middle of a 19-in. TFT-LCD monitor. Depressing the left arrow-key (on a keyboard) caused the portion size to decrease (a smaller picture number was displayed). Pressing the right arrow-key caused the converse. The pictures were loaded with sufficient speed that continuous depression of the left or right arrow key gave the appearance that the change in portion size was "animated." Each trial started with a different and randomly selected portion size. Participants were instructed to "Imagine you are having this food for lunch right now. Select your IDEAL portion size." Once the appropriate portion size had been selected, the participants selected a button marked "continue" and the next trial began. The test foods were presented in a different randomized order for each participant. The code for this and all other computer-based tasks was written in Visual Basic (version 6.0).

Expected satiation: Our measure of expected satiation was obtained using a 'Matched Fullness' task, based on a technique developed previously in our laboratory (Brunstrom & Rogers, 2009). A 400-kcal portion of food was displayed on the left side of a computer screen. Next to this 'standard' we presented a 'comparison' food. The participants were instructed to "Look at the food on the left. Imagine you are having this plate of food for lunch TODAY. Change the portion of food on the right so that both foods will leave you feeling EQUALLY FULL (immediately after they have been eaten)." The comparison food was always pasta and tomato sauce. This food was selected as a common comparison food because we expected it to be extremely familiar to our sample. The remaining eight test foods were presented separately as 'standards' over eight trials. Their order