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Conditioning 'fullness expectations' in a novel dessert

Laura L. Wilkinson[a] and Jeffrey M. Brunstrom[a]

[a]Department of Experimental Psychology, University of Bristol,

12a Priory Road, Bristol, BS8 1TU, England.

Running head: Conditioning fullness expectations

Corresponding author: Laura.Wilkinson@bristol.ac.uk (Laura L. Wilkinson)

Not for publication:
Telephone: +44 (0)117 924 6620
Fax: +44 (0)117 928 8588

Abstract

Calorie-for-calorie, foods differ considerably in the extent to which they are expected to deliver satiation. We sought to demonstrate that flavour-nutrient learning modifies these expectations. On day one, participants (*N*=56) tasted a novel dessert and then completed a measure of expected satiation. Participants then consumed either a low (228 kcal) or high (568 kcal) energy-dense dessert (sensory characteristics matched). On day two, expected satiation was assessed and then intake was measured using an intermediate energy-dense dessert. Expected satiation did increase but only in the high energy-dense condition (17.4%). This difference was not reflected in a measure of intake.

flavour-nutrient learning expected satiation associative learning portion size

human energy density expected satiety

Introduction

Foods differ considerably in the extent to which they are expected to deliver satiety (the extent to which food will stave off hunger) (Brunstrom, Shakeshaft, & Scott-Samuel, 2008). Indeed, when compared on a calorie-for-calorie basis, some are expected to deliver five to six times more satiety than others. This 'expected satiety' may be closely related to 'expected satiation' – the extent to which foods are expected to evoke feelings of 'fullness' at the end of a meal (Brunstrom *et al.*, 2008), and it is highly correlated with the portion sizes that people select (Brunstrom & Shakeshaft, 2008). Therefore, understanding the basis on which these expectations are formed should be given high priority.

Recently, Brunstrom *et al.*, (2008) reported that expected satiety is higher in foods that are more familiar or that are consumed more often. This is important, because it suggests that judgements of this kind are not based solely on unlearned visual cues such as the perceived volume of a food. Instead, judgments may be learned over time, perhaps via an association that forms between the sensory characteristics of a food and subsequent post-ingestive events (Le Magnen, 1957).

Previously, this 'flavour-nutrient learning' has been demonstrated by covertly manipulating the energy density of a novel food. After repeated exposure, participants report a greater increase in the palatability of a high energy-dense (HD) food relative to reports associated with a low energy-dense (LD) food (Booth, Mather, & Fuller, 1982; Brunstrom & Mitchell, 2007). Furthermore, after exposure to a HD version, participants tend to consume a relatively smaller amount of the test food (Yeomans, Leitch, Gould, &

Mobini, 2008; Yeomans, Weinberg, & James, 2005). Since fullness is associated with meal size, we reasoned that expected satiation (fullness) might also be modified by flavour-nutrient associations.

To explore this idea we asked participants to taste a novel dessert and to estimate its expected satiation. Participants then consumed the dessert and provided a second measure of expected satiation the following day. In separate conditions the participants received either a LD or a HD dessert. Learning is indicated by a condition-dependent shift in expected satiation on day two relative to day one. One possibility is that dietary learning is predicted by levels of dietary restraint (Brunstrom, Downes, & Higgs, 2001; Brunstrom & Mitchell, 2007). Therefore, we also included the restraint section of the Dutch Eating Behaviour Questionnaire (van Strien, Frijters, Berger, & Defares, 1986).

As in previous studies (Brunstrom & Shakeshaft, 2008; Brunstrom *et al*., 2008) expectations were estimated using a 'method of constant stimuli.' Briefly, this involves one food of fixed and known energy content being displayed on a computer screen. Next to this 'standard' a different food is displayed. On each trial, the amount of this second 'comparison' food changes, and the participant is asked to indicate which of the two foods will be more filling. After a sufficient number of trials, it is possible to calculate the comparison (*i.e.*, energy) that is expected to be equally as filling as the standard.

On day two we also offered our participants *ad libitum* access to an intermediate energy-dense (ID) version of the dessert. In so doing, we aimed to assess whether changes in expected satiation are reflected in a measure of intake.

Method

Participants

Fifty-six female undergraduate students (mean age = 20.7 [SD=2.6] years) assisted with this study. Vegetarians, vegans and individuals with lactose intolerance were excluded. The mean BMI was 22.8 (SD=3.1). The Faculty of Science Human Research Ethics Committee gave approval for the protocol. All were offered £10 Sterling in remuneration for their assistance with the study. On arrival, participants were allocated alternately to the high or low energy-dense condition.

Novel food

The dessert was formulated using a novel combination of strawberry flavoured Jell-O® (Hartley's, Premier Foods, Cambridgeshire, U.K.) and strawberry flavoured Angel Delight (a powdered pudding mix prepared with semi-skimmed milk; Premier Foods, Cambridgeshire, U.K.). The dessert was 'covertly' manipulated to produce three different formulations, a LD (61 kcal/100g), an ID (97.6 kcal/ 100g), and a HD (152.7 kcal/100g) version. Respectively, these contained 228 kcal, 363 kcal[1], and 568 kcal, each weighing 372g each. Following previous studies (e.g. Brunstrom & Mitchell, 2007), the addition of maltodextrin facilitated the manipulation of energy density while preserving taste and texture characteristics across conditions. The ingredients and macronutrient compositions of these desserts are provided in Table 1. The desserts were developed in our laboratory, where six participants tasted the high, intermediate and low energy-dense formulations and were asked if they were the same or different in respect to appearance, taste and satiation. All participants confirmed the desserts were matched. The LD and HD versions were served in a tall sundae glass, topped with whipped cream and a glacé cherry (weighing approximately 5g in total). The ID version was used on the second day for the measure of expected satiation and for the measure of intake (a large bowl from which the participants could serve themselves).

Measuring expected satiation

The novel food (the standard) was assessed against two commonly consumed 'comparison' foods (1) egg penne (Sainsbury's supermarkets Ltd., Holborn, London) mixed with pasta sauce (sun-dried stir in tomato sauce supplied by Dolmio, Masterfoods, Melton Mowbray, Leicestershire; 152.4 kcal/ 100 g) and (2) oven-baked fries (McCain, McCain Food Ltd., Scarborough, North Yorkshire; 172 kcal/ 100 g). Images (620x542) of each comparison food were presented on a 19-inch VDU.

The novel food (the standard) was physically present during the evaluation. Participants were instructed to taste and consume a single mouthful. During subsequent trials, they were asked to judge whether the picture shown on the screen would fill them up more or less than the novel food in front of them. Responses were registered by keyboard presses. Each comparison food was presented alternately across trials and each was presented 56 times in total. Across trials, the size of the comparison food changed.

The selection of each comparison picture was determined using an adaptive probit estimation algorithm (APE) (Watt & Andrews, 1981). Based on an ongoing assessment of previous responses, this algorithm selects comparison values that are most likely to be centred on a probable match between the standard and the comparison (point of subjective equality, PSE). Subjectively, this means that decision making often becomes more difficult with increasing trial number.

For both comparison foods, the portion that could be displayed ranged from 20 kcal to 1400 kcal. Between these extremes, portions were photographed in 20 kcal increments. 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 each photograph.

Procedure

Participants attended two 40-minute sessions at the same time on consecutive days. Testing took place between 12 pm and 2 pm and participants were instructed to abstain from eating for at least two hours before attending the test sessions. To assess compliance with this request the participants reported the time that they last ate and the nature of the meal.

On arrival, the participants were allocated alternately to either the LD or the HD condition. Participants read an instruction sheet, signed a consent form, and completed our measure of expected satiation. Using visual-analogue rating scales, the participants then rated their liking for the dessert, the extent to which they regarded it as novel, and their current hunger and fullness. Finally, the participants were instructed to consume the dessert in its entirety and then to abstain from eating for at least 2 hours.

On day two the participants were shown the ID dessert and then completed the measure of expected satiation a second time. The participants were then given *ad libitum* access to the ID dessert. This dessert was served in a portion that was larger than could be reasonably consumed in a single meal. Intake was assessed by measuring the amount of food remaining at the end of the meal. At the end of the day the participants completed the DEBQ-restraint scale, and were then debriefed and paid.

Data analysis

Probit analysis was used to calculate a PSE which describes the amount of a comparison food (in kcal) that is judged to be equally as filling as the standard. For a more detailed account of this process see Brunstrom *et al.* (2008). For each participant and each test day, a pair of PSE values was computed, one for fries and another for pasta & sauce. Following previous studies (*e.g.*, Brunstrom *et al.* 2008), these PSE values were log transformed. For each pair of log-transformed PSEs an average (mean) PSE score ($PSE\text{-}ave_{log}$) was computed. A mixed-model ANOVA (day [day 1&2] as a within-subjects factor and condition [HD/LD] as a between-subjects factor) was used to explore these average PSE scores. To consider effects of dietary restraint on learning we repeated this analysis and included restraint as a between-subjects factor. Participants were allocated to a high- or a low-restraint group based on a median split of restraint scores.

Across conditions, intake of the ID novel dessert was compared using an independent samples *t*-test. One participant was excluded from the study because she failed to consume a full portion of the dessert on her first test day.

Results

Participant characteristics

A comparison of restraint, hunger, fullness, novelty, and liking revealed no significant difference in scores across conditions. See Table 2. In the LD condition 17 participants were low restrained and 10 participants were high restrained. In the HD condition 11 were low restrained and 17 were high restrained.

Changes in expected satiation

PSE-ave$_{log}$ values did not differ significantly across test days (mean day one = 1.01, mean day two = 1.04, $F(1,51)= .77$, $p= .38$) or across conditions (mean LD = 1.03, mean HD = 1.02, $F(1,51) = .29$, $p = .59$). However, we did find a significant interaction between these terms ($F(1,51) = 4.84$, $p= .032$).

Tukey post-hoc analysis revealed a significant increase (critical difference at 1% = 0.077, difference = 0.078, $p < .01$) in PSE-ave$_{log}$ values in the HD condition (mean day one = 0.99, mean day two = 1.06). In the LD condition the PSE-ave$_{log}$ values did not differ significantly across test days (mean day one = 1.04, mean day two = 1.02). To illustrate the change in expected satiation we converted PSE-ave$_{log}$ values (for day one and two) into corresponding kcals ($20(10^{\text{PSE-ave}_{\text{log}}})$). On day one, the HD dessert was regarded to be equally as filling as 195 kcal of fries/pasta (combined average given). On day two this value increased by 34 kcal to 229 kcal (a 17.4% change). On day one, the LD dessert was regarded to be equally as filling as 219 kcal of fries/pasta (combined average given). On day two this value decreased to 209 kcal (a 4.6% change).

Our analysis also revealed an effect of dietary restraint which narrowly missed significance (mean low restraint = 0.97, mean high restraint = 1.09, $F(1,51)= 4.03$, $p= .0501$). In the low restraint group, the dessert was regarded to be equally as filling as 187 kcal of fries/pasta (combined average given). In the high restraint group, the dessert was regarded to be equally as filling as 246 kcal of fries/pasta (combined average given). All other interactions failed to reach significance ($p > .05$).

Intake

Across conditions, the difference in intake of the ID dessert was not significant (day 2) (mean LD condition = 114 g (111 kcal), mean HD condition = 116 g (113 kcal), $t(53) = -.093$, $p = .93$). Intake of the ID dessert did not significantly differ across the low and high restraint groups (mean low restraint = 100g (98 kcal), mean high restraint = 131g (128 kcal), $t(53) = -1.32$, $p = .192$).

Discussion

The primary aim of this research was to determine whether expected satiation can change after an association is formed between the sensory characteristics of a food and its post-ingestive consequences. Our findings confirm this is the case. In the HD condition expected satiation increased on day two relative to day one. By contrast, expected satiation shifted relatively little in the LD condition. This result is important, because it complements previous observations that expected satiety is higher in familiar foods (Brunstrom *et al.* 2008). Together, these findings demonstrate that expectations are not based solely on the physical characteristics of food.

In the present study we explored expected satiation. Whether the same learning would be evident in a measure of expected satiety remains to be seen. Unpublished data from our laboratory indicate a close correspondence between expected satiety and satiation. However, the nature of this relationship remains to be explored in detail. In particular, it is unclear whether learned changes in expected satiation and satiety occur independently or in tandem.

A secondary aim was to determine whether exposure to a low- or high-energy dessert influences subsequent intake of an intermediate-energy dessert (day two). As in previous studies (Brunstrom & Mitchell, 2007; Zandstra, Stubenitsky, de Graaf, & Mela, 2002), we found little evidence that meal size is affected by prior exposure (although see Yeomans, Weinberg, and James, 2005). It may be relevant that the dessert tended to be consumed in portions that were considerably smaller than the fixed portions during training (training portions = 372 g, mean portion at test = 115g). Indeed, they were similar to typical portion sizes for chilled dairy desserts in the UK (100-150 g) (Food Standards Agency, 2008). Given this, one possibility is that intake was motivated largely by social norms rather than by changes in expected satiation, and that further exposure might be required for changes in expected satiation to influence intake. Alternatively, it may be relevant that expected satiety is highly correlated with self-selected portion size (Brunstrom & Shakeshaft, 2008). Perhaps, shifts in expected satiety are more likely to influence decisions about meal size (prior to meal onset) rather than the development of satiation towards the end of a meal. In future this prospect might be tested by including an assessment of 'ideal portion size' along with a measure of *ad libitum* eating of the kind that we used here.

If expected satiation is also a good predictor then this may have implications for the long-tem efficacy of specific food products such as those that are designed to promote weight loss. One possibility is that repeated exposure to a low energy-dense food affects its expected satiation, which in turn increases the amount of that food that is desired, thereby undermining its potency as a weight-loss product. A related prospect is that repeated exposure to either a low or a high energy-energy dense food also brings about a change in its hedonic quality (Yeomans, Weinberg, & James, 2005). The role of these shifts in palatability, relative to conditioned changes in expected satiation, remains to be determined.

Contrary to previous work, we found little evidence that learning is modulated by dietary restraint (Brunstrom, Downes, & Higgs, 2000). Instead, on both test days, restrained eaters expected the dessert to be more filling (calorie for calorie) [effect narrowly missed significance p=.0501]. Potentially, this reflects a fundamental characteristic of dietary restraint. Future studies should seek to replicate this result with a larger sample size.

A further avenue of research relates to the key conditions that promote learning. In the context of our paradigm, we suspect that learning is more likely to occur when the test food is highly novel and when its energy density differs considerably across conditions. Additionally, it is also possible that learning is determined by the context in which a food is presented, specifically, whether the test food is presented on its own or in combination with other foods. Meals often comprise a combination of food items (*e.g.*, vegetables, meat, and breads). When a novel test food is included alongside other foods the opportunity for flavour-nutrient learning may be degraded.

References

Booth, D. A., Mather, P., & Fuller, J. (1982). Starch content of ordinary foods associatively conditions human appetite and satiation, indexed by intake and eating pleasantness of starch-paired flavours. *Appetite, 3*(2), 163-184.

Brunstrom, J. M., Downes, C. R., & Higgs, S. (2001). Effects of dietary restraint on flavour-flavour learning. *Appetite, 37*(3), 197-206.

Brunstrom, J. M., & Mitchell, G. L. (2007). Flavor-nutrient learning in restrained and unrestrained eaters. *Physiology & Behavior, 90*(1), 133-141.

Brunstrom, J. M., & Shakeshaft, N. G. (2008) Measuring affective (liking) and non-affective (expected satiety) determinants of portion size and food reward. *Appetite.*

Brunstrom, J. M., Shakeshaft, N. G., & Scott-Samuel, N. E. (2008). Measuring expected satiety' in a range of common foods using a method of constant stimuli. *Appetite, 51(3),* 604-614.

Food Standards Agency. (2008). Trends in portion sizes in the U.K: A preliminary review of published information. Retrieved January 25, 2009, from http://www.food.gov.uk/multimedia/pdfs/reviewportions.pdf.

Le Magnen, J. (1957). Le mecanisme d'establishment d'un appetite differential pour des regimes de diverses densites caloriques. *Journal of Physiology (Paris), 49*, 1105-1107.

van Strien, T., Frijters, J. E. R., Berger, G. P. A., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*(2), 295-315.

Watt, R. J., & Andrews, D. P. (1981). APE: Adaptive Probit Estimation of Psychometric functions. *Current Psychological Review, 1*, 205-214.

Yeomans, M. R., Leitch, M., Gould, N. J., & Mobini, S. (2008). Differential hedonic, sensory and behavioral changes associated with flavor-nutrient and flavor-flavor learning. *Physiology & Behavior, 93*(4-5), 798-806.

Yeomans, M. R., Weinberg, L., & James, S. (2005). Effects of palatability and learned satiety on energy density influences on breakfast intake in humans. *Physiology & Behavior, 86*(4), 487-499.

Zandstra, E. H., Stubenitsky, K., De Graaf, C., & Mela, D. J. (2002). Effects of learned flavour cues on short-term regulation of food intake in a realistic setting. *Physiology & Behavior, 75*(1-2), 83-90.

Footnote 1: The energy content of the ID formulation deviated very slightly from the average energy content of the HD and LD versions. This reflected constraints relating to the production of large batches of samples.

Tables

Table 1. Ingredients and macronutrient composition of the novel food. Separate values (g/ml and kcal) are given for the LD, ID, and HD versions.

	LD		ID		HD	
Ingredients	g	kcal	g	kcal	g	kcal
Strawberry sugar-free Jell-O®	5	15				
Saccharine sweetener	0.02	0				
Strawberry Jell-O®			51	150	51	150
Maltodextrin					60	240
Strawberry angel delight	30	142	30	142	22	107
	ml	kcal	ml	kcal	ml	kcal
Semi-skimmed milk	142	71	142	71	142	71
Water	568	0	568	0	568	0
Macronutrient composition						
Protein (g)	9		8		8	
Carbohydrate (g)	29		63		118	
Fat (g)	9		9		7	
Total Weight (g)	372		372		372	
Energy (kcal)	228		363		568	
Kcal/100g	61		98		153	

Table 2. For each condition, mean (*S.E.M.*) restraint score, and hunger, fullness, novelty, and liking on day one. Differences between conditions were assessed using *t*-tests. Associated *t* values, degress of freedom (*df*), and *p* values are also included.

	LD		HD		*df*	*t*	*p*
	Mean	*S.E.M*	Mean	*S.E.M*			
Hunger (mm)	66.4	3.9	72.4	2.7	53	1.28	.21
Fullness (mm)	21.2	2.6	24.4	2.9	53	.81	.42
Novelty (mm)	67.2	3.4	60.9	4.2	53	1.17	.25
Liking (mm)	42.9	4.2	37.3	4.2	53	.94	.35
Restraint	2.5	.12	2.8	.16	53	1.26	.21