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Presenting a food in multiple smaller units increases expected satiety

Rose E. Oldham-Cooper[*, 1], Laura L. Wilkinson [1, 2], Charlotte A. Hardman [3], Peter J. Rogers, Jeffrey M. Brunstrom

School of Experimental Psychology, University of Bristol, 12a Priory Road, Bristol, UK

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ABSTRACT

Presentation of the same amount of a food in multiple smaller units ('segmentation') has been shown to reduce food intake and increase estimates of the amount of food consumed. However, this effect has been demonstrated for *ad libitum* food intake only. In the majority of cases, meals are not consumed *ad libitum*, but are pre-selected and consumed in their entirety, Expected satiety (ES; the anticipated capacity of a portion of food to relieve hunger between meals) is an excellent predictor of portion size selection. This study tested the hypothesis that segmentation increases ES. It was also hypothesised that perceived volume (PV) may account for the relationship between segmentation and ES. Sixty-eight participants made computer-based ES and PV judgments for equicaloric portions of three test foods (salted peanuts, spaghetti Bolognese, and chicken tikka masala), which were presented in either a single unit or as multiple smaller units (three or six units). Results revealed a consistent effect of segmentation on ES - foods presented in multiple smaller units were expected to deliver significantly greater satiety than when presented in a single unit ($p < 0.005$). Furthermore, results indicated that the effect of segmentation on ES was attributable to an increase in PV. ES plays an important role in determining the portion sizes that people select. Therefore, awareness of the effect of segmentation on ES may help to inform the design of foods that confer benefits for healthy weight maintenance.

1. Introduction

A number of studies have demonstrated that presenting a food in multiple small units reduces subsequent food intake and increases estimates of the amount consumed (Marchiori, Waroquier, & Klein, 2011, 2012; Wadhera, Capaldi, & Wilkie, 2012; Weijzen, Liem, Zandstra, & de Graaf, 2008). In one study, Chang et al. (2012) served rice in either an amorphous mass or in smaller units (rice balls). Participants consumed less rice when it was served in smaller units relative to an amorphous mass (323 kcal vs. 412 kcal respectively, a 28% difference). In another study, coloured potato chips inserted at evenly-spaced intervals in a packet of stackable potato chips led to higher and more accurate consumption estimates, and a reduction in food intake, relative to 'unsegmented' packets of potato chips (Geier, Wansink, & Rozin, 2012). This is a relatively robust finding and not limited to judgements about food (e.g, Pelham, Sumarta, & Myaskovsky, 1994 reported evidence for use of a 'numerosity heuristic' in judgements of quantity for non-food items).

However, to date studies have tended to focus on effects of segmentation on *ad libitum* intake and the effect on beliefs about food remains unexplored. In many cases (if not the majority) meals are pre-selected and then consumed in their entirety (Fay, Ferriday, et al., 2011). On this basis, it is argued that meal size is often planned and determined before a meal begins (Brunstrom, 2011). In a number of studies, Brunstrom et al. suggest that 'expected satiety' (ES; expected relief from hunger between meals) plays a key role in portion-size selection (Brunstrom & Rogers, 2009; Brunstrom, Brown, Hinton, Rogers, & Fay, 2011). ES independently predicts self-selected 'ideal' portion sizes, both in computerised measures (Brunstrom & Rogers, 2009; Brunstrom & Shakeshaft, 2009) and in actual portion selections (Wilkinson et al., 2012). It is also associated with the amount (kcal) of food consumed in a meal (Wilkinson et al., 2012) and with the satiety experienced after it has terminated (Brunstrom et al., 2011; Fay, Hinton, Rogers, & Brunstrom, 2011). One possibility, therefore, is that segmentation also influences ES.

* Corresponding author.
E-mail address: r.oldham-cooper@nhs.net (R.E. Oldham-Cooper).
[1] These authors are joint first authors on this work.
[2] Present address: Department of Psychology, Swansea University, Singleton Park, Swansea, UK.
[3] Present address: Department of Psychological Sciences, University of Liverpool, Liverpool, UK.

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In the current study, we tested the hypothesis that the ES of a food can be increased by presenting it in multiple small units, and that the extent to which this increase is observed is dependent on the degree of segmentation (number of units) but not on the specific food or the absolute portion size that is presented. To test this proposition, equicaloric portions of different foods were presented in one, three, and six units. ES was assessed using a previously validated 'method of adjustment' (see Brunstrom, 2011 for review). Previously, this approach has been used to quantify relative differences in ES across foods. In this specific instance we also considered alternative approaches that provide an indication of the *absolute* effect of segmentation on ES. We selected a novel implementation of magnitude estimation, an approach often used by psychophysicists to quantify absolute intensity and size judgments (Stevens, 1957, 1975). This provides a means of calculating a % increase in anticipated relief from hunger that is produced by increasing levels of segmentation. Finally, following other studies (e.g., Brogden & Almiron-Roig, 2010), we also assessed ES using a visual-analogue scale.

A further objective was to determine whether segmentation changes the perceived volume (PV) of a food. Specifically, when presented in multiple smaller units, the physical size of a food may appear larger relative to when it is presented as an (equicaloric) single unit. Previously, measures of PV appeared to explain some of the variation in ES across foods (Brunstrom, Collingwood, & Rogers, 2010; Keenan, Brunstrom, & Ferriday, 2015). Therefore, the effect of segmentation on ES might be explained by a change in PV. To explore this idea we quantified the PV of our test foods (using a method of adjustment and magnitude estimation) and used these measures to determine the extent to which effects of segmentation of ES can be explained by changes in PV.

2. Method

2.1. Overview

Participants evaluated the ES and PV of three test foods; salted peanuts, spaghetti Bolognese and chicken tikka masala (supplementary materials). These foods were selected because they are commonly consumed in the UK. Each food was presented and evaluated in five different portions; 200, 400, 600, 800 and 1000 kcal. Each portion was presented in one of three different levels of 'segmentation', (a) a single combined portion (low segmentation), (b) three equal segments (medium segmentation), and (c) six equal segments (high segmentation). In combination, this yielded a total of 45 test stimuli (3 foods x 5 portions x 3 levels of segmentation). All participants evaluated every test stimulus and completed all measures. Participants could pause at any point during each stimulus block to minimise fatigue.

2.2. Participants

Sixty-eight participants (20 male and 48 female) were recruited from the undergraduate population at the University of Bristol and from the surrounding area. Vegetarians and vegans were excluded. Participants received either a course credit or £7 (sterling) in return for their participation. Ethical approval was granted by the local Faculty of Science Research Ethics Committee.

2.3. Image preparation and test foods

Table 1 contains a summary of the macronutrient composition of the three test foods; two 'main meals' (spaghetti Bolognese, tikka masala) and a snack (salted peanuts). All were supplied by Sainsbury's Ltd, UK. Images were captured using a Nikon D50 camera and were presented on a 24-inch widescreen TFT-LCD monitor. Test foods were prepared according to manufacturer instructions and photographed on a square 300 mm by 300 mm plate. Each test food was photographed with three levels of segmentation and in five portion sizes (see supplementary materials), rendering 15 images in total. We selected rice with vegetables (Uncle Ben's Express Golden Vegetable Rice, Knorr) as a comparison food in the method of adjustment task (see 'expected satiety' below). Images were taken of 101 portions that spanned the range 10 kcal–1000 kcal with logarithmic spacing. Each portion was presented on a round 255-mm diameter plate.

Table 1
Calorie and macronutrient content of the comparison foods (all values typical per 100 g).

	Kcal	Protein (g)	Carbohydrate (g)	Fat (g)	Fibre (g)
Spaghetti Bolognese	162	7.3	16.4	7.1	1.7
Chicken tikka masala	178	8.1	19.5	7.2	1.5
Jumbo salted peanuts	639	29.5	13.3	52	5.8
Rice with vegetables	150	3.1	29.6	2.1	0.7

2.4. Measures

The following measures were implemented using custom software written in Microsoft Visual Basic 6.0.

Appetite ratings. Participants rated their hunger and fullness on a 100-mm visual-analogue scale (VAS) anchored by "not at all" and "extremely" on the left and right, respectively.

Food familiarity. Participants were asked to indicate their familiarity with an un-segmented 200-kcal portion of each test food, presented in randomised order. The familiarity task required participants to indicate, using one of 4 drop-down menus (per day; per week; per month; per year), how often they consumed each comparison food. The familiarity scores were converted to a common unit – number of times consumed per year.

Expected satiety (method of adjustment.) Following an earlier study (Brunstrom & Rogers, 2009), in separate trials, participants adjusted the size of a 'comparison food' to match the satiety that was expected from each test food (the 'standard food'). Respectively, the standard and the comparison food were presented on the left- and right-hand side of the screen. Participants responded to the instruction "In this task you will be shown two foods. In this task you should: 1. Look at the food on the left. Imagine you are having this plate of food for lunch today and you won't be eating again until your evening meal; 2. Change the portion of food on the right so that both foods will keep you feeling satisfied (*i.e.*, stave-off hunger) for the same amount of time." The order of the test foods was randomised across participants and the initial comparison portion was selected randomly in each trial. Participants used the arrow keys on the keyboard to manipulate the size of the comparison food.

Expected satiety (magnitude estimation). The purpose of the magnitude-estimation measure of ES was to remove the need for participants to manipulate one food to create a match with a different comparison food (as in the method of adjustment task, described above). In this task, the test food was presented on the right-hand side of the screen. On the left-hand side the participants were shown an unsegmented (single unit) 300-kcal portion of the same type of food. Participants were presented with a horizontal scale with a single short vertical line that intersected the horizontal 15 mm from the left. Participants were told that this line represented the extent to which the food on the left would provide relief from hunger until the next meal (Fig. 1). The position of the vertical mark on the line and the amount of the food (standard) shown on