Expected satiation alone does not predict actual intake of desserts

Étienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel, Claire C. Gaudichon, Daniel Tomé, Gilles Fromentin

► To cite this version:

Étienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel, Claire C. Gaudichon, et al.. Expected satiation alone does not predict actual intake of desserts. *Appetite*, 2018, 123, pp.183-190. 10.1016/j.appet.2017.12.022 . hal-01783985

HAL Id: hal-01783985

<https://hal.science/hal-01783985>

Submitted on 19 Sep 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Expected satiation alone does not predict actual intake of desserts

Etienne Guillocheau, Olga Davidenko, Agnès Marsset-Baglieri, Nicolas Darcel, Claire Gaudichon, Daniel Tomé, Gilles Fromentin

(i) UMR Physiologie de la Nutrition et du Comportement Alimentaire, AgroParisTech, INRA, Université Paris-Saclay, 75005, Paris, France

Corresponding author: Olga Davidenko, Physiologie de la Nutrition et du Comportement Alimentaire, AgroParisTech, INRA, Université Paris-Saclay, 16 rue Claude Bernard, F-75 005 Paris - E-mail: olga.davidenko@agroparistech.fr – Phone number +331 44 08 86 37

ABSTRACT

The degree to which consumers expect foods to satisfy hunger, referred to as expected satiation, has been reported to predict food intake. Yet this relationship has not been established precisely, at a quantitative level. We sought to explore this relationship in detail by determining whether expected satiation predicts the actual intake of semi-solid desserts. Two separate experiments were performed: the first used variations of a given food (eight apple purées), while the second involved a panel of different foods within a given category (eight desserts). Both experiments studied the consumption of two products assigned to volunteers based on their individual liking and expected satiation ratings, given *ad libitum* at the end of a standardised meal. A linear model was used to find predictors of food intake and included expected satiation scores, palatability scores, BMI, age, sex, TFEQ-R, TFEQ-D, water consumption during the meal, reported frequency of eating desserts, and reported frequency of consuming tested products as explanatory variables. Expected satiation was a significant predictor of actual food intake in both experiments (apple purée: $F(1,97) = 18.60$, $P < 0.001$; desserts: $F(1,106) = 9.05$, $P < 0.01$), along with other parameters such as product palatability and the volunteers' age, sex and food restriction (variation explained by the model/expected satiation in the experiments: 57%/23% and 36%/17%, respectively). However, we found a significant gap between expected and actual consumption of desserts, on group and on individual level. Our results confirm the importance of expected satiation as a predictor of subsequent food intake, but highlight the need to study individual consumption behaviour and preferences in order to fully understand the role of expected satiation.

KEYWORDS: Expected satiation; Food intake; Palatability.

INTRODUCTION

It has been shown that most people are able to plan their meals in terms of portion size (Fay et al., 2011; Hinton et al., 2013). Consumers can predict the degree to which foods are expected to satisfy hunger when compared on a calorie-for-calorie basis, which is referred to as expected satiation (Brunstrom & Rogers, 2009). What is less studied today is whether expected satiation is quantitatively related to actual food intake. It was reported that the “perceived fullness” score was the best predictor of actual food intake among military personnel, since it could explain half of the variance associated with food intake (Pilgrim & Kamen, 1963). In addition, expected satiation was found to be significantly correlated with the ideal portion size estimated by subjects (Brunstrom & Rogers, 2009; Brunstrom & Shakeshaft, 2009). Despite this, very little work has been done to connect expected satiation with real food intake: only one study by Wilkinson and colleagues (2012) suggested that among factors such as liking, appetite, food reward, body mass index (BMI) and food restriction and disinhibition scores, expected satiation might be a good predictor of food intake. However, this study was performed using only one food (pasta with sauce), and it would be difficult to generalise such findings to other commonly consumed foods. Expected satiation is also dependent on context. Indeed, expected satiation is more important when people are hungry than when sated (Brogden & Almiron-Roig, 2010). Given this, desserts present several interests to study expected satiation: first, they constitute a particular food group which is well-understood by the general public yet offers a variability of sensory and nutritional characteristics; second, because desserts are consumed at the end of a meal when people are already starting to experience satiation, a situation that allows to control the nutritional state of volunteers in ecological conditions. Despite this, little work has yet been done on desserts (Forde, Almiron-Roig, & Brunstrom, 2015). The objective of this study was

therefore to expand our knowledge by studying the correlation between expected satiation and actual food intake using a range of desserts in the context of a meal.

This study had two objectives: (1) to confirm whether expected satiation could predict the actual food intake of desserts, and whether the accuracy of this predictor depends on the satiating power of the dessert or on its sensory characteristics; (2) to study the degree to which expected satiation can be considered as a measure of the amounts of food actually consumed, at both the group and individual levels.

MATERIALS AND METHODS

We present here the data resulting from two independent experiments which shared the same experimental design but featured different sets of products. The first study used eight apple purées only varying in texture (“apple purée” experiment), while the second used eight desserts commonly found on the French market (“dessert” experiment), which were more dissimilar. The objective of this second experiment was to verify whether the results obtained in the first experiment are generalisable to a larger group of foods. According to French law, the experimental protocols were approved by the French National Agency for Medicines and Health Products Safety (ANSM) and the Ethics Committee for Research Ile de France VII (“apple purée” experiment: #2013-A00339-36; “dessert” experiment: #2015-A00089-40). All participants received financial compensation for their participation.

Participants

Two different panels of volunteers were recruited for the experiments in Paris (France) and its surrounding area. All subjects were healthy non-smokers, aged from 18 to 60 years, with a normal weight (BMI ranging from 18 to 25 kg/m²) and not on a diet. They did not display any food allergies or dislikes regarding the foods proposed, and were not taking any medications

known to affect appetite. Pregnant or breast-feeding women, athletes in training, people with a score ≥ 9 on the restraint subscale (TFEQ-R) or ≥ 8 on the disinhibition subscale (TFEQ-D) of the Three-Factor Eating Questionnaire (Lesdema et al., 2012; Stunkard & Messick, 1985) were excluded from the study. Moreover, since both experiments involved foods usually consumed as desserts, we only recruited volunteers who stated that they were generally used to eating a dessert at the end of their meals. The power calculation estimated that 54 subjects were necessary for each experiment to show a 33-g difference in food intake (1/3 of a standard portion) between the least and most satiating products with a power of 0.80. In order to ensure spontaneous and natural behaviour during the sessions, the true purpose of the study was not disclosed to the participants; instead they were told that the aim was to adjust the recipes of the products (apple purées or desserts).

Fifty-four participants (14 M, 40 F) were recruited for the “apple purée” experiment between January and June 2014, according to the recruitment criteria described above. Their mean (SEM) ages and BMI values were 25.0 (0.6) years and 20.9 (0.3) kg/m², respectively, and their mean (SEM) restriction and disinhibition scores were 4.6 (0.2) and 4.9 (0.3), respectively.

Fifty-seven participants (13 M, 44 F) were recruited for the dessert experiment between February and June 2015, according to the recruitment criteria described above. Their mean (SEM) ages and BMI values were 24.1 (0.5) years and 21.1 (0.2) kg/m², respectively, and their mean (SEM) restriction and disinhibition scores were 5.2 (0.3) and 5.1 (0.3), respectively.

Study products

For each experiment, a set of eight products was designed so that products within the set would match two criteria: (1) similar energy content (maximum difference of 20 kcal/100 g

among products), and (2) possibility to visually discriminate the products. The “apple purée” experiment used eight apple purées obtained from one initial preparation (chunky apple purée with no added sugar from Andros®). The purees were adjusted in a way similar to that used during a previous study by our team (Parizel et al., 2016) and varied in terms of particle size, pulp content and the addition of apple fragments (see Table 1 for details), which resulted in perceived visual and texture differences. The “dessert” study used a set consisting of eight desserts selected from those commonly available in France and described during the same previous study (Parizel et al., 2016). This assortment was based on a free sorting test carried out by 32 untrained subjects (who were not the same as the participants in the present study) that allowed us to choose the most dissimilar desserts among a set of 16 products. These desserts included fruit purees, dairy products, custards and puddings; these differed with respect to several sensory modalities (colour, texture, flavour) but had similar nutritional contents (see Table 2 for details).

Evaluation of expected satiation

Expected satiation was evaluated using a variation of the method developed by (Wilkinson et al., 2012). For each test food, 16 photographs were taken using a high-resolution digital camera. The lighting conditions and viewing angles were identical for all photographs. The test foods were arranged in identical transparent bowls (Duralux®, 135 mm diameter). The portion size displayed on the photographs increased linearly in 25 kcal steps, from 25 kcal in photograph 1 to 400 kcal in photograph 16. Photograph 4 corresponded to a standard (100 kcal) portion. Each photograph was identified by a random three-figure number, and the 16 photographs of each test food were gathered in a single picture displayed on a tablet (Samsung® Galaxy Tab 2 10.1, Android 4.1.2). During the evaluation of expected satiation, the participants were asked to look simultaneously at the 16 pictures, and then to “select the

picture corresponding to the portion which they thought they needed to eat in order to feel full at the end of lunch”. In addition, the volunteers were given the bowl that had been used for the pictures of each test food, thus enabling them to estimate the real quantity associated with each picture.

Experimental procedure

Each experiment consisted in four sessions that took place at lunch time. The participants were asked to attend at the same time for all sessions, between 11.30 a.m. and 1.30 p.m., with a one-week minimum gap between each session. They were instructed to eat the same evening meal the day before each test day and the same breakfast on each test day, and were asked to consume no food or drinks, except for plain water, between their breakfast and the session. During the sessions, the volunteers were served lunch in a quiet room free of any food references or other sources of distraction. Each participant was seated alone at a table, and visual contact between the volunteers was not possible. At the start of each session, the participants were first asked to indicate, on a 100-mm unmarked visual analogue scale (VAS), how they were feeling at the time they completed the following questions: How hungry do you feel now? (VAS anchors: not hungry at all–extremely hungry); How full do you feel now? (not full at all–extremely full); How strong is your desire to eat now? (very weak–very strong); How much food do you think you could eat now? (nothing at all–a large amount); How thirsty do you feel now? (not thirsty at all–extremely thirsty) (using a French translation of the questions recommended by Blundell et al., 2010).

Session 1: Expected satiation

After answering the appetite questionnaire, the participants were first of all served a main course composed of pasta with tomato sauce (Penne Tomate Basilic, Panzani®) and 500 mL water. The pasta dish was served *ad libitum* and the participants were instructed to eat as

much as they wanted. The amounts of pasta and water consumed were then weighed and recorded with 0.1 g accuracy. Once the participants had eaten the pasta to fullness, they were asked to score its palatability using a 100-mm VAS (question: “How much do you like this dish?”, anchors: not at all-very much indeed). Next, the participants evaluated the expected satiation associated with the set of products used during the experiment to which they belonged (apple purées or desserts). The products were presented using a sequential monadic procedure, following a Williams Latin square design (Williams, 1949). First, a 25g sample of the test food was served to the subjects and they were instructed to taste it and score its palatability using a 100-mm VAS similar to that used for the pasta. Next, the subjects scored the expected satiation of the product, as described previously.

Product assignment

After the session on expected satiation, two foods from the set were assigned individually to each volunteer as a function of their individual expected satiation scores: the product for which the volunteer selected the smallest portion (referred to as “the most satiating product” below), and the product for which the volunteer selected the biggest portion (referred to as “the least satiating product” below). This was done in order to study whether the subjects behave the same when they consume products providing different levels of expected satiety. Since it has been shown that palatability may impact satiation (Bobroff & Kissileff, 1986), pairs of products were selected in such a way as to minimise differences in palatability, whenever possible.

Sessions 2, 3 and 4: Food intake

During three subsequent sessions, the actual food intake of the two individually assigned products was measured. A single product was provided during each session. Two sessions featured the least satiating product in order to evaluate the stability of each participant’s behaviour. The order of sessions was randomised. In the same way as for the expected

satiation session, the volunteers were first asked to complete the appetite questionnaire. Next, they were served the same amount of pasta as they had eaten during the expected satiation session, and were told to clean the plate (all participants complied with the instructions during all sessions). 500 mL water was also available. After cleaning their plates, the volunteers scored the palatability of the pasta dish, as described above. They were then given a bowl containing 400 kcal of one of the individually assigned products as their dessert, and were instructed to eat it until they felt full. Afterwards, they were asked to score the palatability of the product using the same method as during the expected satiation session. Any remaining amounts of dessert and water (for the “dessert” experiment) were weighed and recorded with an accuracy of 0.1-g. At the end of the last food intake session, the subjects were asked to state their frequency of consumption of the study desserts. For the “apple purée” experiment, they were asked to answer the question: “How often do you eat apple purée?” They had to choose between four answers: “At least once a week”, “At least once a month”, “At least once a year”, “Less than once a year”. For the “dessert” experiment, the identities of the individually assigned products were disclosed to the participants and they were asked the same question for each dessert separately.

Data analysis

The effect of the product on palatability scores collected during the expected satiation session was analysed using one-way ANOVA. The effect of product and palatability on expected satiation scores (expressed as energy (kcal) and volume (in L)) were analysed using ANCOVA. Bonferroni *post hoc* corrections were applied for multiple comparisons.

For each session, the appetite score of each participant was calculated as follows:

$$\text{Appetite score} = \frac{(\text{Hunger} + \text{Prospective consumption} + \text{Desire to eat}) + (100 - \text{Fullness})}{4}$$

Before further analysis, the stability of food behaviour was assessed using the data acquired during food intake sessions involving the least satiating product. Linear mixed models were used to analyse appetite scores, palatability scores and the amount of product consumed (as energy or as volume). The session, BMI, age, sex, TFEQ-R and TFEQ-D were used as fixed effects and the participant as a random effect in order to adjust for repeated measures.

The stability of appetite scores, palatability ratings, and amount of water consumed during the food intake sessions (“dessert” experiment only) for products during each session was assessed using linear mixed models with the session, BMI, age, sex, TFEQ-R and TFEQ-D as fixed effects and the participant as a random effect. Tukey *post hoc* tests were used to estimate the means.

A linear model was constructed in order to assess predictors of food intake (as energy or as volume). This model included expected satiation scores (as energy or as volume), palatability scores, mean amount of water consumed during the food intake sessions (for the “dessert” experiment only), BMI, age, sex, TFEQ-R, TFEQ-D, reported frequency of eating a dessert at the end of a meal, and reported frequency of consuming the test foods as explanatory variables.

Because expected satiation and actual food intake data were not collected using the same method, these parameters could not be compared using a single procedure. Four linear mixed models were therefore used to compare (1) expected satiation vs. actual food intake (separately for two individually selected products), and (2) actual food intake of two individually selected products (separately for expected satiation session and food intake sessions). All models included BMI, age, sex, TFEQ-R, TFEQ-D, mean amount of water consumed during the food intake sessions (for the “dessert” experiment only), reported frequency of eating a dessert at the end of a meal and reported frequency consumption of test foods as fixed factors and the participant as a random factor.

Individual intake data were studied by computing the difference between actual food intake and expected satiation relative to the two individually assigned products for each subject. We considered there was a match between expected satiation and actual food intake if this difference was less than 1/3 of a portion (33 g).

All statistical computations were carried out using R 3.2.1. for Windows (<http://www.cran.r-project.org/>), using the “car” and “lme” packages, and type II tests. P-values <0.05 were considered to be statistically significant. All data are presented as mean ± SEM.

RESULTS

EXPERIMENT 1: APPLE PURÉES

Stability of food behaviour and appetite sensations

For food intake sessions involving the least satiating apple purée, there was no significant effect of the session on appetite status ($\chi^2(1) = 0.003$, NS), palatability scores ($\chi^2(1) = 0.62$, NS) and the amount of apple purée actually consumed (energy content and volume: $\chi^2(1) = 0.14$, NS). Therefore, the mean values of the two sessions were used for subsequent analyses. No significant effect of the session was seen regarding the appetite status of volunteers ($\chi^2(1) = 5.62$, NS) during the four study sessions.

Expected satiation session: palatability and expected satiation for the entire apple purée set

We found a significant product effect on palatability scores ($F(7,408) = 3.22$, $P < 0.01$), during the expected satiation session (see Table 1). There was no significant effect of product on expected satiation scores, expressed as energy ($F(7,407) = 0.72$, NS) or as volume ($F(7,407) = 0.73$, NS), but the palatability effect on expected satiation was significant (energy and volume: $F(1,407) = 117.9$, $P < 0.001$).

Palatability scores for individually assigned apple purées

The most satiating apple purée was rated as being significantly less palatable than the least satiating apple purée during the expected satiation session ($P < 0.001$, see Figure 1A). During the food intake sessions the most satiating apple purée consistently received lower palatability scores than the least satiating apple purée ($P < 0.01$). The volunteers were consistent in their ratings of the least satiating apple purée, since there was no significant difference between ratings given during the expected satiation session and the food intake sessions ($P = 0.87$). By contrast, the most satiating apple purée was significantly more appreciated during the food intake session than during the expected satiation session ($P < 0.001$).

Expected satiation and food intake

We found a significant difference in expected satiation ratings between the most satiating and least satiating apple purées (energy: $\chi^2(1) = 51.46$, $P < 0.001$, see Figure 1B; volume: $\chi^2(1) = 52.19$, $P < 0.001$ see Figure 1C). This difference remained throughout the food intake sessions as the most satiating apple purée was significantly less consumed than the least satiating apple purée (analysis in terms of both energy and volume gave the same result: $\chi^2(1) = 4.83$, $P < 0.05$). However, the actual food intake of the most satiating apple purée was significantly larger (energy: $\chi^2(1) = 48.37$, $P < 0.001$; volume: $\chi^2(1) = 47.51$, $P < 0.001$) than expected, while there was no significant difference between expected satiation and the actual food intake of the least satiating apple purée (energy: $\chi^2(1) = 1.96$, NS; volume: $\chi^2(1) = 1.93$, NS).

Predictors of food intake

The linear model revealed that actual food intake (as energy) was predicted by expected satiation ($F(1,97) = 18.60$, $P < 0.001$), sex ($F(1,97) = 17.66$, $P < 0.001$), TFEQ-R ($F(1,97) =$

20.95, $P < 0.001$), age ($F(1,97) = 5.50$, $P < 0.05$) and the palatability score given during the food intake session ($F(1,97) = 6.64$, $P < 0.05$). The model accounted for 57% of the variance associated with food intake ($R^2 = 0.57$). Expected satiation was the first predictor in terms of explained variance (23%). After adjustment for the reported frequency of eating a dessert at the end of a meal, and the reported frequency of consuming apple purées, these parameters remained significant predictors of food intake. The adjusted model accounted for 58% of the variance in food intake ($R^2 = 0.58$). Comparable results were obtained when expressing food intake as volume. Expected satiation, sex, TFEQ-R, age and palatability scores at the food intake session remained good predictors of actual food intake, even when adjusting for experience parameters. Likewise, the adjusted model accounted for more than the half of the variance associated with food intake when expressed as volume ($R^2 = 0.58$).

Consistency between food intake and expected satiation at an individual level

Individual food intake was plotted against expected satiation (as energy) for the most and least satiating apple purées (see Figure 3). The actual food intake of the most satiating apple purée was higher than the expected satiation in all participants except one. However, some participants consumed less of the least satiating apple purée than expected, and the differences between expected and actual consumption were within a broader range for this product. After matching individual values, we found that only five subjects consumed within 1/3 of a portion (+/- 33 g or +/- 18.7 kcal) of the expected satiation of both products. Four more subjects were within the limits for the most satiating puree only and 11 for the least satiating puree only.

EXPERIMENT 2: DESSERTS

Stability of food behaviour and appetite sensations

There was no significant effect of the session on appetite status ($\chi^2(1) = 0.40$, NS), palatability scores ($\chi^2(1) = 0.09$, NS) and the amount of the least satiating dessert consumed during two food intake sessions (energy: $\chi^2(1) = 0.23$, NS; volume: $\chi^2(1) = 0.32$). Therefore, as for the “apple purée” experiment, the mean values of the two sessions were used for subsequent analyses. No significant effect of session was found on the appetite status of volunteers ($\chi^2(1) = 5.54$, NS) during the four study sessions. No significant effect of session was found on the amount of water consumed during the food intake sessions ($\chi^2(2)=1.1092$, NS).

Expected satiation session: palatability and expected satiation for the entire dessert set

We found a product effect on the palatability scores ($F(7,447) = 2.82$, $P < 0.01$, see Table 2) collected during the expected satiation session. There was no significant effect of product ($F(7,447) = 0.48$, NS) on expected satiation scores when expressed as energy. However, we observed an significant effect of product ($F(7,447) = 4.29$, $P < 0.001$) when expected satiation was expressed as volume. As in the “apple purée” experiment, the effect of palatability on expected satiation scores was significant (energy: $F(1,447) = 98.70$, $P < 0.001$; volume: $F(1,447) = 98.22$, $P < 0.001$).

Palatability scores of individually assigned desserts

The most satiating dessert was rated as being significantly less palatable than the least satiating dessert during the expected satiation session ($P < 0.001$, see Figure 2A). The most satiating dessert was consistently associated with a lower palatability score during the food intake sessions when compared to the least satiating dessert ($P < 0.001$). No significant difference in palatability scores was found between the expected satiation session and food intake sessions ($P = 0.99$ and $P = 0.13$ for the least and most satiating desserts, respectively).

The mean palatability for each dessert was therefore determined and used for subsequent calculations.

Expected satiation and actual food intake

As expected, the expected satiation scores assigned to the most and least satiating desserts were significantly different (energy: $\chi^2(1) = 115.24$, $P < 0.001$, see Figure 2B; volume: $\chi^2(1) = 90.97$, $P < 0.001$, see Figure 2C). However, actual intakes did not differ between these two desserts (energy: $\chi^2(1) = 0.32$, NS; volume: $\chi^2(1) = 1.15$, NS). Participants consumed significantly more of the most satiating dessert than expected (energy: $\chi^2(1) = 24.60$, $P < 0.001$; volume: $\chi^2(1) = 23.16$, $P < 0.001$), while the reverse applied for the least satiating dessert (energy: $\chi^2(1) = 14.03$, $P < 0.001$; volume: $\chi^2(1) = 15.88$, $P < 0.001$).

Predictors of food intake

The linear model revealed that actual food intake (expressed as energy) was predicted by palatability ($F(1,105) = 22.56$, $P < 0.001$), expected satiation ($F(1,105) = 7.92$, $P < 0.01$) and TFEQ-R ($F(1,105) = 4.99$, $P < 0.05$). The model accounted for 36% of the variance associated with food intake ($R^2 = 0.36$). Expected satiation was the first predictor (17% expected variance) and palatability explained 11% of the total variance. Expected satiation and palatability, but not the TFEQ-R, remained significant after adjustment for the reported frequency of eating a dessert at the end of a meal, and the reported frequency of consuming both contrasting desserts. The adjusted model accounted for 40% of the variance associated with food intake ($R^2 = 0.40$). When actual food intake was expressed as volume, palatability and expected satiation remained significant predictors of food intake before ($F(1,105) = 16.51$, $P < 0.001$ and $F(1,105) = 4.38$, $P < 0.05$, respectively) and after adjustment ($F(1,105) = 11.92$, $P < 0.001$ and $F(1,105) = 5.56$, $P < 0.05$, respectively), and the mean volume of water

consumed during the session became a significant predictor as well (before adjustment: $F(1,105) = 7.59, P < 0.01$; after adjustment: $F(1,105) = 8.15, P < 0.01$). The adjusted model accounted for more than a third of the variance associated with food intake ($R^2 = 0.35$).

Consistency between actual food intake and expected satiation at an individual level

Individual differences between actual food intake and expected satiation (as energy) regarding the most and least satiating apple purées are plotted on Figure 4. Most volunteers (75%) consumed more of the most satiating dessert than expected. We observed more mixed results with the least satiating dessert. Only five subjects consumed within 1/3 of a portion (+/- 33 g or +/- 33.4 kcal) from the expected portions of both desserts. Twenty-four more were within the range for one of the products (nine for the least satiating and 15 for the most satiating, respectively).

DISCUSSION

Our experiments studied the relationship between expected satiation and the actual intake of common semi-liquid desserts. We used a set of versions of a single food (the “apple purée” experiment, products varying in texture only) and a set of different foods within a given category (the “dessert” experiment, products varying in different characteristics) in order to generalize the results of the first experiment to a wider food category. Furthermore, the use of individually assigned products allowed us to study the relationship between expected satiation and actual intake using a within-subject design, and to test the robustness of the relationship between these parameters for different levels of expected satiation. During both experiments, we found that expected satiation was a significant predictor of the actual intake of selected products. Nevertheless, the quantities actually consumed were close (within 33 g) to the expected portions in only a small minority of subjects (9%), while actual intakes were stable

across the sessions. We must therefore conclude that expected satiation could not be considered as an alternative measure of food intake in the case of spoonable desserts, and other factors should be taken into account.

Our study showed that expected satiation is a significant predictor of the actual intake of desserts, alongside palatability and other factors such as age, sex or TFEQ-R scores. Our findings were partly in contradiction with previous results which had shown that expected satiation was the only significant predictor of intake (Wilkinson et al., 2012). Such a difference in the results might have been caused by our choice to work with desserts, products that are more likely to be consumed for their hedonic value than the pasta with sauce used in Wilkinson's study. The variance associated with palatability was therefore higher in our experiment.

While expected satiation performed quite well as a predictor of actual intake within the linear model, the results were more nuanced when expected satiation scores and actual intakes were compared quantitatively. With the exception of the least satiating apple purée, a significant difference was observed between mean actual intake and mean expected satiation, in line with the findings of a previous study (P S Hogenkamp, Mars, Stafleu, & de Graaf, 2012). In order to determine the proportion of participants who could be considered as "consistent", we fixed a threshold of congruence between actual intakes and expected satiation. Although this threshold was chosen to be relatively permissive (1/3 of a standard portion), only ten out of 111 participants (9%) fell within this threshold for both the most and the least satiating products, and a further 39 (35%) fell within this threshold for only one of the two products.

The difference between expected and actual intake could be explained by a significant change in mean palatability scores between sessions for the most satiating apple purée (35 and 52 for the expected satiation session and food intake session, respectively) (Bobroff & Kissileff, 1986), because palatability was identified as a predictor of actual intake. But although

palatability remained constant in the “dessert” experiment, we observed even less consistency between expected and actual intakes during the second study, thus showing that factors other than palatability might be involved. One of such factors might be the nature of the products used. Indeed, purées and desserts eaten with a spoon are usually consumed in individual pre-packaged portions of comparable size. While the intakes recorded *ad libitum* were likely to reflect a real willingness to eat, they still might have been influenced by previous experiences with pre-packaged foods. This could explain why we did not observe difference in actual intake between the most and the least satiating product in the “dessert” study. Previous experience with such foods might have driven the subjects to consume a portion close to the habitual portion, disregarding the difference in palatability (high enough in case of desserts). Besides, it is possible that during the “expected satiation” session, the task of judging eight products simultaneously led to a more precise categorisation during the expected satiation session and caused more differentiation in palatability and expected satiation by a process comparable to a hedonic contrast effect where “good things (here, better liked products) make less good things even worse” (Hayes, DePasquale, & Moser, 2011; Parizel et al., 2015; Zellner, Allen, Henley, & Parker, 2006). Compared to this, the food intake sessions involved a more natural situation of consuming one dessert and partly abolished satiation and palatability differences. Finally, the amount of water intake displayed a significant influence on the volume of desserts consumed. Still, since the actual consumption was not systematically lower than anticipated, water did not suppress the intake, and besides, water intake was not a predictor of caloric intake.

Beyond its influence on actual intake, in both experiments palatability also appeared to be correlated with expected satiation itself, although the study design does not allow to draw a causality relationship. By contrast, the product effect appeared to be a less important determinant of expected satiation, particularly in the “apple purée” experiment. This was

contrary to what had been expected, because the apple purées we used varied in texture and previous studies had shown that texture influences expected satiation (Pleunie S Hogenkamp, Stafleu, Mars, Brunstrom, & de Graaf, 2011; McCrickerd, Chambers, Brunstrom, & Yeomans, 2012). However, previous findings were based on much more diverse sets of products, ranging from solid to liquid, while the apple purées in our experiment were all semi-solid and varied in density and the amount of chunks rather in terms of their food form. The same applied to the set of products used in the “dessert” experiment. However, in the second experiment, differences in expected satiation could be explained by the product factor when it was expressed in volume rather than in calories. This might signal an adjustment of consumption for energy rather than for volume, as the product set in the “dessert” experiment was more variable in caloric density ($SD = 0.094$) than the set used for the “apple purée” experiment ($SD = 0.005$). How energy density can be detected at the stage of expected satiation still needs to be studied.

Our experiments used foods that are usually consumed as desserts and they were served at the end of a lunch. This design served two purposes: first, it was more ecological because the desserts are chosen and consumed at the end of the meal, and second, the standardised main course allowed us to control the appetite status of the volunteers, because it has been shown that appetite status impacts expected satiation (Brogden & Almiron-Roig, 2010). This design differed crucially from that of previous studies involving a variety of test foods from different categories. For instance, the study by (Brunstrom, Shakeshaft, & Scott-Samuel, 2008) included main courses (pizza, boiled potatoes), but also snack foods (crackers, potato crisps) and other types of foods (fresh banana). Our design explains the overall stability of expected satiation among test foods, as well as that of liking scores and actual intakes. However, our experiments only used semi-solid foods that could be eaten with a spoon. The

outcomes might have been different if we had included solid desserts such as pies or fruit pieces, or liquids such as milkshakes.

CONCLUSIONS

Our results may generate conflicting views regarding the importance of expected satiation to food intake in humans. On the one hand, our study confirmed that expected satiation is a predictor of actual intake, which is consistent with previous studies. However, we also showed that other parameters, and especially palatability, were also predictors of intake. The importance of expected satiation could therefore be questioned if it were to be considered as a means of controlling food intake, especially in case of highly palatable foods. Reasoning at an individual level, taking into account personal preferences, is necessary if the objective is to limit the consumption of highly palatable foods such as desserts, for example in order to control weight gain. Further research is now needed to fully understand the role of expected satiation as it relates to food intake, in different individuals and food groups.

Funding acknowledgement. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

- Blundell, J., De Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluch, A., ... Westerterp, M. (2010). Appetite control: methodological aspects of the evaluation of foods. *Obesity Reviews*, 11(3), 251–270. <https://doi.org/10.1111/j.1467-789X.2010.00714.x>
- Bobroff, E. M., & Kissileff, H. R. (1986). Effects of changes in palatability on food intake and the cumulative food intake curve in man. *Appetite*, 7(1), 85–96.
- Brogden, N., & Almiron-Roig, E. (2010). Food liking, familiarity and expected satiation selectively influence portion size estimation of snacks and caloric beverages in men. *Appetite*, 55(3), 551–5. <https://doi.org/10.1016/j.appet.2010.09.003>
- Brunstrom, J. M., & Rogers, P. J. (2009). How many calories are on our plate? Expected fullness, not liking, determines meal-size selection. *Obesity (Silver Spring, Md.)*, 17(10), 1884–90. <https://doi.org/10.1038/oby.2009.201>
- Brunstrom, J. M., & Shakeshaft, N. G. (2009). Measuring affective (liking) and non-affective (expected satiety) determinants of portion size and food reward. *Appetite*, 52(1), 108–14. <https://doi.org/10.1016/j.appet.2008.09.002>
- Brunstrom, J. M., Shakeshaft, N. G., & Alexander, E. (2010). Familiarity changes expectations about fullness. *Appetite*, 54(3), 587–90. <https://doi.org/10.1016/j.appet.2010.01.015>
- 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), 604–14. <https://doi.org/10.1016/j.appet.2008.04.017>
- Fay, S. H., Ferriday, D., Hinton, E. C., Shakeshaft, N. G., Rogers, P. J., & Brunstrom, J. M. (2011). What determines real-world meal size? Evidence for pre-meal planning. *Appetite*, 56(2), 284–9. <https://doi.org/10.1016/j.appet.2011.01.006>
- Forde, C. G., Almiron-Roig, E., & Brunstrom, J. M. (2015). Expected Satiety: Application to Weight Management and Understanding Energy Selection in Humans. *Current Obesity Reports*, 4(1), 131–140. <https://doi.org/10.1007/s13679-015-0144-0>
- Hayes, J. E., DePasquale, D. A., & Moser, S. E. (2011). Asymmetric dominance as a potential source of bias in hedonic testing. *Food Quality and Preference*, 22(6), 559–566. <https://doi.org/10.1016/j.foodqual.2011.03.006>
- Hinton, E. C., Brunstrom, J. M., Fay, S. H., Wilkinson, L. L., Ferriday, D., Rogers, P. J., & de Wijk, R. (2013). Using photography in « The Restaurant of the Future ». A useful way to assess portion selection and plate cleaning? *Appetite*, 63, 31–5. <https://doi.org/10.1016/j.appet.2012.12.008>
- Hogenkamp, P. S., Mars, M., Stafleu, A., & de Graaf, C. (2012). Repeated consumption of a large volume of liquid and semi-solid foods increases ad libitum intake, but does not change expected satiety. *Appetite*, 59(2), 419–24. <https://doi.org/10.1016/j.appet.2012.06.008>
- Hogenkamp, P. S., Stafleu, A., Mars, M., Brunstrom, J. M., & de Graaf, C. (2011). Texture, not flavor, determines expected satiation of dairy products. *Appetite*, 57(3), 635–41. <https://doi.org/10.1016/j.appet.2011.08.008>
- Irvine, M. A., Brunstrom, J. M., Gee, P., & Rogers, P. J. (2013). Increased familiarity with eating a food to fullness underlies increased expected satiety. *Appetite*, 61(1), 13–8. <https://doi.org/10.1016/j.appet.2012.10.011>

- Lesdéma, A., Fromentin, G., Daudin, J.-J., Arlotti, A., Vinoy, S., Tomé, D., & Marsset-Baglieri, A. (2012). Characterization of the Three-Factor Eating Questionnaire scores of a young French cohort. *Appetite*, 59(2), 385–390. <https://doi.org/10.1016/j.appet.2012.05.027>
- McCrickerd, K., Chambers, L., Brunstrom, J. M., & Yeomans, M. R. (2012). Subtle changes in the flavour and texture of a drink enhance expectations of satiety. *Flavour*, 1(1), 20. <https://doi.org/10.1186/2044-7248-1-20>
- Parizel, O., Sulmont-Rossé, C., Fromentin, G., Delarue, J., Labouré, H., Benamouzig, R., & Marsset-Baglieri, A. (2015). The structure of a food product assortment modulates the effect of providing choice on food intake. *Appetite*. <https://doi.org/10.1016/j.appet.2015.11.018>
- Pilgrim, F. J., & Kamen, J. M. (1963). Predictors of Human Food Consumption. *Science (New York, N.Y.)*, 139(3554), 501–502. <https://doi.org/10.1126/science.139.3554.501>
- Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research*, 29(1), 71–83. [https://doi.org/10.1016/0022-3999\(85\)90010-8](https://doi.org/10.1016/0022-3999(85)90010-8)
- Wilkinson, L. L., Hinton, E. C., Fay, S. H., Ferriday, D., Rogers, P. J., & Brunstrom, J. M. (2012). Computer-based assessments of expected satiety predict behavioural measures of portion-size selection and food intake. *Appetite*, 59(3), 933–938. <https://doi.org/10.1016/j.appet.2012.09.007>
- Williams, E. (1949). Experimental Designs Balanced for the Estimation of Residual Effects of Treatments. *Australian Journal of Chemistry*, 2(2), 149. <https://doi.org/10.1071/CH9490149>
- Zellner, D. A., Allen, D., Henley, M., & Parker, S. (2006). Hedonic contrast and condensation: Good stimuli make mediocre stimuli less good and less different. *Psychonomic Bulletin & Review*, 13(2), 235–239. <https://doi.org/10.3758/BF03193836>

TABLE 1

Formulation parameters, mean ($\pm$ SEM) palatability scores and expected satiation of the products used during the apple purée experiment.

	Formulation parameters			Energy (kcal/100 g)	Density (100 mm scales)	Expected satiation		
	Grinding ¹	Added pulp ²	Apple fragments ³			kcal	L litre??	
Hd	2	-1	0	54.0	0.986	40 ± 4	61.0 ± 6.3	0.11 ± 0.01
HdF	2	-1	1	56.2	0.986	50 ± 3	62.7 ± 6.0	0.12 ± 0.01
HC	2	1	0	58.1	0.995	42 ± 3	64.7 ± 6.3	0.12 ± 0.01
HCF	2	1	1	57.2	0.992	44 ± 3	56.2 ± 4.8	0.10 ± 0.01
L	1	0	0	56.0	0.993	53 ± 3	66.2 ± 5.4	0.12 ± 0.01
LF	1	0	1	55.6	1.000	56 ± 3	68.7 ± 5.1	0.13 ± 0.01
LC	1	1	0	58.9	0.994	51 ± 3	68.6 ± 5.5	0.13 ± 0.01
LCF	1	1	1	57.6	0.988	53 ± 3	62.5 ± 5.2	0.12 ± 0.01
Heterogeneity	-	-	-	-	-	<i>P</i> < 0.01	<i>P</i> = 0.72	<i>P</i> = 0.73

¹An initial apple purée was ground at two levels: weak (1) and strong (2).

²Addition of pulp to ground apple purées (1); No added pulp (0); Dilution of ground apple purée (-1).

³Addition of apple fragments to ground apple purées (1); No added apple fragments (0).

TABLE 2

Macronutrient and energy content, mean ($\pm$ SEM) palatability scores and expected satiation of the products used during the dessert experiment.

	Energy (kcal/100 g)	Carbohydrates (g/100 g)	Fat (g/100 g)	Protein (g/100 g)	Density (100 mm scales)	Expected satiation	
						kcal	L
Apple purée	94.0	22.0	0.1	0.3	1.23	64 $\pm$ 3	164.0 $\pm$ 9.7 0.14 $\pm$ 0.01
Chocolate dessert cream	112.0	16.7	3.6	3.1	1.15	56 $\pm$ 4	149.6 $\pm$ 9.2 0.12 $\pm$ 0.01
Natural yogurt ¹	95.5	12.2	3.4	4.2	1.08	58 $\pm$ 3	145.6 $\pm$ 8.6 0.14 $\pm$ 0.01
Protein-rich yogurt ²	96.5	9.1	2.4	8.7	1.01	63 $\pm$ 3	152.2 $\pm$ 9.2 0.16 $\pm$ 0.01
Prune yogurt	97.0	12.0	3.3	3.5	0.97	56 $\pm$ 4	138.2 $\pm$ 8.6 0.15 $\pm$ 0.01
Raspberry puree	93.0	20.0	0.2	0.8	1.14	63 $\pm$ 4	147.4 $\pm$ 10.1 0.14 $\pm$ 0.01
Raspberry-blueberry yogurt	108.0	12.0	5.3	2.5	1.08	68 $\pm$ 2	161.0 $\pm$ 7.9 0.14 $\pm$ 0.01
Rice pudding	113.0	20.7	2.2	2.4	1.21	49 $\pm$ 3	132.5 $\pm$ 9.1 0.10 $\pm$ 0.01
Heterogeneity	-	-	-	-	-	$P < 0.01$	$P = 0.85$ $P < 0.01$

¹The nutritional composition takes account of the addition of 6.64 g sugar per 100 g of natural yogurt, in order to obtain an energy density close to 100

kcal/100 g.

²The nutritional composition takes account of the addition of 5.78 g sugar per 100 g of protein-rich yogurt, in order to obtain an energy density close to 100

kcal/100 g.

1381
1382
1383
1384
554

1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421

FIGURE LEGENDS

FIGURE 1

“Apple purée” experiment: mean ($\pm$ SEM) palatability score (A), mean ($\pm$ SEM) amount (kcal) (B) and mean ($\pm$ SEM) volume (L) (C) for both contrasting apple purées during the expected satiation session and food intake sessions. The value for the least satiating apple purée during the food intake session corresponds to the mean intakes during the food intake sessions that involved this product.

Within-product differences: $P < 0.001$ (***).

Within-session differences: $P < 0.05$ (#), $P < 0.01$ (†), $P < 0.001$ (§).

FIGURE 2

Dessert experiment: mean ($\pm$ SEM) palatability score (A), mean ($\pm$ SEM) amount (kcal) (B) and mean ($\pm$ SEM) volume (L) (C) for both contrasting desserts during the expected satiation session and food intake sessions.

The value for the least satiating dessert during the food intake session corresponds to the mean intakes during the food intake sessions that involved this product.

Within-product differences: $P < 0.001$ (***).

Within-session differences: $P < 0.001$ (§).

FIGURE 3

Analysis of individual consumption (“apple purée” experiment). The actual intakes by participants of individually selected apple purées plotted against the expected satiation of each of the two products. (•) corresponds to the most satiating apple purée. (°) corresponds to the least satiating apple purée (for each data point, the mean value of the two intake sessions for

this product has been plotted). The solid line represents the area of no differences between food intake and expected satiation. Hatched lines indicate the “consistency threshold” of ± 33 g (1/3 of a standard portion; 18.7 kcal for the “apple purée” experiment).

FIGURE 4

Analysis of individual consumption (“dessert” experiment). The actual intakes by participants of individually selected desserts plotted against the expected satiation of each of the two products. (•) corresponds to the most satiating dessert. (°) corresponds to the least satiating dessert (for each data point, the mean value of the two intake sessions for this product has been plotted). The solid line represents the area of no differences between food intake and expected satiation. Hatched lines indicate the “consistency threshold” of ± 33 g (1/3 of a standard portion; 33.4 kcal for the “dessert” experiment).

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4