Appetite 95 (2015) 81–88

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

Energy-dense snacks can have the same expected satiation as sugar-containing beverages

Ashley A. Martin*, Liam R. Hamill, Sarah Davies, Peter J. Rogers, Jeffrey M. Brunstrom

Nutrition and Behaviour Unit, School of Experimental Psychology, University of Bristol, Bristol UK

ARTICLE INFO

Article history:
Received 13 January 2015
Received in revised form
25 May 2015
Accepted 8 June 2015
Available online 27 June 2015

Keywords:
Sugar sweetened beverages
Satiety
Low energy sweetener
Viscosity
Learning
Expected satiation
Portion size
Texture

ABSTRACT

Sugar-sweetened beverages (SSBs) are thought to be problematic for weight management because energy delivered in liquid form may be less effective at suppressing appetite than solid foods. However, little is known about the relative 'expected satiation' (anticipated fullness) of SSBs and solid foods. This is relevant because expected satiation is an important determinant of portion selection and energy intake. Here, we used a method of constant stimuli to assess the expected satiation of test meals that were presented in combination with different caloric and non-caloric beverages (500 ml) (Experiment 1 and 2), as well as with high-energy solid snack foods (Experiment 2). All energy-containing beverages and snack foods were presented in 210 kcal portions. Both experiments found that expected satiation was greater for meals containing caloric versus non-caloric beverages (201.3 ± 17.3 vs. 185.4 ± 14.1 kcal in Experiment 2; $p < 0.05$). Further, Experiment 2 showed that this difference was greater in participants who were familiar with our test beverages, indicating a role for learning. Notably, we failed to observe a significant difference in expected satiation between any of the caloric beverages and snack foods in Experiment 2 (range: 192.5–205.2 kcal; $p = 0.87$). This finding suggests that it may be more appropriate to consider beverages and solid foods on the same continuum, recognizing that the expected satiation of some solid foods is as weak as some beverages.

Consumption of caloric beverages has increased over the last 20 years in tandem with the rate of obesity (Bleich, Wang, Wang, & Gortmaker, 2009; Wang, Bleich, & Gortmaker, 2008). Recent estimates indicate that children and adults consume approximately 14–20% of their daily energy intake from beverages (Drewnowski, Rehm, & Constant, 2013; Ng, Mhurchu, Jebb, & Popkin, 2012; Slining & Popkin, 2013); Sugar-sweetened beverages (SSBs) have received particular attention, being associated with increased energy intake and weight gain (Fiorito, Marini, Francis, Smiciklas-Wright, & Birch, 2009; Malik, Pan, Willett, & Hu, 2013), in addition to metabolic perturbances (Bray & Popkin, 2013; Fagherazzi et al., 2013). Not surprisingly, it is now common advice to reduce or eliminate SSBs from one's diet (Hu, 2013; Pan et al., 2013; Services, 2010).

Part of the reason that SSBs are thought to contribute to weight gain is because beverages appear to suppress appetite and energy intake less than solid foods (de Graaf, 2011). Most of this evidence comes from preload studies that have examined the prandial and post-prandial responses of participants who consume caloric liquids versus sensory-matched, equicaloric semi/-solid foods. These studies show that liquids generate less satiation and satiety than higher-viscosity foods (Mattes, 2006; Mattes & Rothacker, 2001; Tsuchiya, Almiron-Roig, Lluch, Guyonnet, & Drewnowski, 2006; Wolf, Bray, & Popkin, 2008). Consistent with this observation, when offered access to otherwise identical liquid and semi-solid foods, low viscosity is associated with greater *ad libitum* intake (Hogenkamp, Mars, Stafleu, & de Graaf, 2012; Zijlstra, Mars, deWijk, Westerterp-Plantenga, & de Graaf, 2008) and poor energy compensation at a subsequent test meal (DiMeglio & Mattes, 2000; Flood-Obbagy & Rolls, 2009).

These findings have tended to promote a polarized position whereby liquids are assumed to always produce less satiety than solid foods. Consistent with this proposition, it has been suggested that liquids are inherently less satiating than solid foods because liquids are consumed more rapidly (de Wijk, Zijlstra, Mars, de Graaf, & Prinz, 2008; Zijlstra, Mars, De Wijk, Westerterp-Plantenga, & De Graaf, 2008) and pass more quickly through the gastrointestinal tract (Juvonen et al., 2009; Marciani et al., 2001; Zhu, Hsu, & Hollis,

* Corresponding author. Nutrition and Behaviour Unit, School of Experimental Psychology, University of Bristol, 12a Priory Road, Bristol, BS8 1TU, UK.
E-mail address: ashley.martin@bristol.ac.uk (A.A. Martin).

http://dx.doi.org/10.1016/j.appet.2015.06.007

2013) than solids, and because liquids are often consumed very rapidly, which limits the satiety that is generated by oral exposure (for reviews, see de Graaf, 2011; de Graaf & Kok, 2010; Hogenkamp & Schioth, 2013).

Others have cautioned that the difference between liquid and solid calories may be overstated, and that factors other than viscosity may be as important, if not more so, for determining the satiating properties of a food (e.g., Almiron-Roig, Chen, & Drewnowski, 2003; Almiron-Roig, Palla et al., 2013). Indeed, we suspect that comparisons between 'liquid' and 'solid' calories may be of limited benefit because this level of analysis fails to capture the large differences in satiety that are generated even across solid food forms (Brunstrom, Shakeshaft, & Scott-Samuel, 2008; Holt, Brand-Miller, Petocz, & Farmakalidis, 1995). There are several solid foods that are thought to contribute to weight gain on the very basis that they fail to generate enough satiety (Blundell & Macdiarmid, 1997; Prentice & Jebb, 2003). Likewise, there are some liquids, such as soup, that generate excellent satiety responses (Flood & Rolls, 2007; Himaya & Louis-Sylvestre, 1998; Mattes, 2005).

Rather than asking whether beverages categorically deliver less satiation than solid foods, a more practical approach may be to evaluate the satiation of different beverages against the *continuum* of satiety responses that might otherwise be observed in a range of solid foods. Recent work from our group has used this approach to profile the 'expected satiety' of a variety of solid foods, documenting four to five fold differences in the amount of satiety these foods are expected to confer (Brunstrom et al., 2008). These expectations have been shown to be an excellent predictor of the number of calories individuals self-select and ultimately consume (Wilkinson et al., 2012). Moreover, this kind of meal planning appears to be extremely common (Fay et al., 2011).

We are aware of only a few studies that have examined the relationship between expected satiety and food form (i.e., liquid vs. solid). Hogenkamp et al. measured the expected satiation of custards that were presented in a liquid, semi-liquid, semi-solid, or solid form (Hogenkamp, Stafleu, Mars, Brunstrom, & de Graaf, 2011). They observed that participants' judgments of expected satiation increased with the thickness of the custard. This observation was replicated in a subsequent nutrient conditioning experiment (Hogenkamp et al., 2012). While these results demonstrate that the expected satiation of energy-containing liquids differs from sensory-matched solid foods, these two studies did not investigate the expected satiation of liquids consumed as beverages. This is an important distinction as consuming a liquid in the context of a 'beverage' versus a 'food' has been shown to impact its satiating effects (e.g., Mattes, 2005).

To our knowledge, only two studies have measured the expected satiation of commercially-available beverages. One of these explored the effects of liking, familiarity, and expected satiation on portion-size selection using a range of snack foods, including a bottle of SSB (Brogden & Almiron-Roig, 2010). Calorie-for-calorie, the SSB was expected to deliver the same amount of satiation as some solid snack foods (e.g., chocolate bar, muffin) and less satiation than others (e.g., crisps, ice cream). More recently, Almiron-Roig et al. examined participants' ability to judge the portion sizes of 33 different snacks and meals, including four caloric beverages (i.e., SSB, milk, orange juice, and hot chocolate) (Almiron-Roig, Solis-Trapala, Dodd, & Jebb, 2013). They observed that participants equally underestimated the number of standard portions that were contained in a range of low-to-medium energy-dense food items, regardless of whether the item was a snack, a mixed meal, or a beverage. Although neither of these studies investigated the relationship between food form and expected satiation explicitly, their results support our suspicion that the expected satiation of beverages does not always differ from solid foods.

There were three goals for the present study. The first was to explore whether people discriminate between non-caloric and caloric beverages when judging the expected satiation of a meal. This was accomplished in Experiment 1 using a computer-based task that was designed to assess the expected satiation of meals presented in combination with a sugar-sweetened beverage (e.g., SSB), a low-energy sweetener beverage (LES), or water. This effect was replicated in Experiment 2 with a design which also allowed us to establish the relative contribution of calories versus carbonation to the expected satiation of these beverages. Our second objective was to compare the expected satiation of beverages relative to two solid foods. This was accomplished in Experiment 2, where we repeated our measures of the different beverage meals and compared these conditions with meals in which the beverage was replaced with a portion of solid snack food that was equicaloric to the calorie-containing beverages (210 kcals).

Our third objective was to explore individual differences in our participants' judgments of expected satiation. Previous research has shown that familiarity is a strong predictor of expected satiety (e.g., Brunstrom, Shakeshaft, & Alexander, 2010). There is also some evidence that the impact of a sweetened beverage on appetite is dependent on whether an individual typically consumes non/-caloric versions of that beverage (Appleton & Blundell, 2007; Appleton, Rogers, & Blundell, 2004). For these reasons, we hypothesized that individuals who frequently consumed SSBs might be more familiar with their satiating properties and, thus, more likely to discriminate between SSBs and non-caloric beverages (LES or water). This prediction was tested in Experiments 1 and 2 by examining the relationships between participants' intakes of SSBs and LESs, and their judgments of expected satiation.

1. Experiment 1

1.1. Method

1.1.1. Participants

Sixty-eight undergraduates from the University of Bristol (UK) participated in the experiment for class credit (60 F/8 M; Age: $M = 19.5$, $SD = 1.7$). Their BMI ranged from 15.7 to 31.0 ($M = 21.5$, $SD = 2.8$). Current dieters and individuals taking a medication (other than contraceptive pills) that might influence appetite were excluded. Ethical approval was obtained from the local Faculty of Science Human Research Ethics Committee.

1.1.2. Materials

1.1.2.1. Test stimuli. Participants evaluated the expected satiation of two reference meals, each of which consisted of a savoury snack and a chocolate bar. One meal comprised a 32.5 g bag of salted potato chips (Walkers, Leicester, England) and a Mars® bar (i.e., chocolate-covered nougat; Mars Incorporated UK, Slough, England) (total energy content: 431 kcals). The other meal comprised a 100 g bag of salted peanuts and a Twix® bar (i.e., chocolate-covered biscuit with caramel; Mars Incorporated UK, Slough, England) (total energy content: 869 kcals). These snack items were selected because they are widely available and commonly consumed throughout the UK.

In this study, we elected to use two reference meals in order to generate greater variety across trials and to reduce participant fatigue. The critical manipulation was that each of these reference meals was presented in compound with three different beverages: a SSB (Coca-Cola), a LES (Diet Coke), and a matched volume (500 ml) of water; this yielded six possible meal—beverage combinations (hereafter referred to as 'test meals'). By contrasting participants' judgments of meals that were identical in all respects except for the beverage, we were able to assess the relative