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Does modifying the thick texture and creamy flavour of a drink change portion size selection and intake?

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Abstract

Previous research indicates that a drink's sensory characteristics can influence appetite regulation. Enhancing the thick and creamy sensory characteristics of a drink generated expectations of satiety and improved its actual satiating effects. Expectations about food also play an important role in decisions about intake, in which case enhancing the thick and creamy characteristics of a drink might also result in smaller portion size selection. In the current study forty-eight participants (24 female) completed four test days where they came into the laboratory for a fixed-portion breakfast, returning two hours later for a mid-morning drink, which they could serve themselves and consume as much as they liked. Over the test days, participants consumed an iso-energetic drink in four sensory contexts: thin and low-creamy; thin and high-creamy; thick and low-creamy; thick and high-creamy. Results indicated that participants consumed less of the thick drinks, but that this was only true of the female participants; male participants consumed the same amount of the four drinks regardless of sensory context. The addition of creamy flavour did not affect intake but the thicker drinks were associated with an increase in *perceived* creaminess. Despite differences in intake, hunger and fullness ratings did not differ across male and female participants and were not affected by the drinks sensory characteristics. The vast majority of participants consumed all of the drink they served themselves indicating that differences in intake reflected portion size decisions. These findings suggest women will select smaller portions of a drink when its sensory characteristics indicate that it will be satiating.

Keywords: Beverage; sensory characteristics; satiation; viscosity; creaminess; expectations

Introduction

Energy-containing drinks are reported to have a weaker satiety value than energy-matched 'foods', such as solid and semi-solid items and liquid soups (Hulshof, Degraaf, & Weststrate, 1993; Mattes, 2005, 2006a; Mourao, Bressan, Campbell, & Mattes, 2007; Tournier & Louis-Sylvestre, 1991). Oro-sensory characteristics of foods are important for the development of satiety (Cecil, Francis, & Read, 1998, 1999), triggering learned salivatory and gastrointestinal cephalic phase responses which are thought to aid the digestion of nutrients and enhance the experience of satiety (Mattes, 1997, 2006b; Woods, 1991). Evidence that energy consumed in liquid form elicits a weak cephalic phase response (Teff, 2010; Teff, Devine, & Engelman, 1995) suggests that the strength of associations formed between a drink's sensory characteristics and its post-ingestive effect is weak; possibly because they are consumed fast, and this reduced oral exposure time may limit the strength of its oro-sensory signal and subsequent learning (Mars, Hogenkamp, Gosses, Stafleu, & De Graaf, 2009). As a result, energy consumed as a drink may not be *expected* to be satiating, and the potential for these expectations to influence decisions about consumption is the focus of the present study.

Resent research from our laboratory supports the idea that the sensory characteristics of a drink can limit its satiety value: drinks varying in thick texture and creamy flavour were expected to have different satiating effects (McCrickerd, Chambers, Brunstrom, & Yeomans, 2012). The thicker drinks were expected to be more filling (expected satiation) and to suppress hunger to a greater extent (expected satiety) than thin versions, regardless of their actual energy content. The addition of creamy flavours did not affect expected satiety but did enhance the expectation that the drinks would be filling, presumably because perceived creaminess has both textural (thickness and smoothness) and flavour (dairy, vanilla and sweetness) attributes (de Wijk, Terpstra, Janssen, & Prinz, 2006; Kirkmeyer & Tepper, 2005) typically associated with nutrients. Indeed, energy compensation following a drink preload was improved by modifying its creamy texture and flavour to better signify the presence of the nutrients (Bertenshaw, Lluch, & Yeomans, 2013; Yeomans & Chambers, 2011). This fits with the Satiety Cascade Model (Blundell, Rogers, & Hill, 1987), which proposes that early cognitive and sensory information is integrated with later post-ingestive and post-absorptive signals to suppress appetite after an eating episode. However, the Satiety Cascade also predicts that sensory characteristics and beliefs about the satiety value of food strongly influence satiation (the process of ending a meal or eating episode) and therefore the amount people eat (Blundell et al., 2010; Blundell, et al., 1987; Brunstrom, 2011). So if a person expects a drink to be filling because it is thick and creamy, as our previous research suggests, they may select a smaller portion size and/or consume less of that drink.

So far research has demonstrated that increasing the viscosity of a liquid did result in decreased *ad libitum* consumption, but whether this reduction is based on a the belief that a thicker product would be more filling is less clear. Hogenkcamp, Mars, Stafleu and de Graaf (2012) provided participants with 1000g portions of a custard product as either a lemon-flavoured liquid or a meringue-flavoured and “caramel” coloured semi-solid, both to be consumed from a large bowl with a spoon. Participants expected the thicker custard to be most filling and consumed approximately 30% less of that custard compared to the thin version. However, because the colour and flavour were not matched across the thick and thin versions, the extent to which differences in intake can be attributed to viscosity alone is limited. In a drink context, Zijlstra, Mars, de Wijk, Westerterp-Plantenga and de Graaf (2008) found similar reductions in intake of an iso-energetic semi-solid chocolate milk compared to a less viscous liquid version, which were presented in 1.5 litre opaque cartons and frequently replaced so the serving could not be finished. The researchers suggest this was due to a difference in eating rate between the products because when eating rate was standardised participants consumed a similar amount of the thick and thin versions. Indeed, *ad libitum* consumption from a ‘bottomless’ portion is a good measure of satiation, but is likely to emphasis factors such as eating rate, stomach distension and appetitive sensations, whilst limiting the opportunity for participants to plan, see and adjust the amount of food they consume based on visual and olfactory cues and pre-existing expectations about its satiating effects. Instead, expectations held about the satiating value of foods are an important determinant of self-selected portion size (Wilkinson et al., 2012) and portion size decisions are a regular feature of everyday eating behaviour, alongside consuming all of the food selected (Fay et al., 2011).

The present study aimed to extend the previous findings that thick texture and creamy flavours can modify expectations and enhance satiety, by determining whether such sensory manipulations also influence actual self-selected intake of a drink and assessing the relative contribution of satiety-relevant texture and flavour cues. Participants were able to select the amount of a drink to consume across four different sensory contexts identical to those used in our previous research (McCrickerd, et al., 2012): thin and low-creamy flavour; thin and high-creamy flavour; thick and low-creamy flavour; thick and high-creamy flavour. It was predicted that participants would consume less of the thicker drinks than the thinner ones, as thick texture generates strong expectations of satiety, and that the addition of a creamy flavours would have more subtle effects on intake. A secondary prediction was that the self-served drink would be consumed in its entirety.

Method and Materials

Participants

Forty-eight participants (24 female) completed the study "investigating the effect of breakfast on mood and alertness". Participants were recruited from a volunteer database of staff and students at the University of Sussex. Participants were selected to be non-smokers, not currently dieting or diagnosed with an eating disorder, without allergies or aversions to any of the test food ingredients and not taking prescription medication. On average, participants were 20.8 years (range = 18-52 years, *SD* = 5.3), with a BMI of 22.5 kg/m^2 (range = 18-30 kg/m^2, *SD* = 2.8) and mean dietary restraint score of 7.1 for males (range = 1-16, *SD* = 4.4) and 6.7 for females (range = 1-15, *SD* = 3.8), measured using the Three Factor Eating Questionnaire (TFEQ: Stunkard & Messick, 1985). Male and female participants did not differ in age, restraint and BMI. The research was approved by the University of Sussex Life Science Research Ethics Board.

Design

A three-factor mixed design was used to assess the effect of drink texture (thin vs. thick) and the addition of creamy flavours (low-creamy vs. high-creamy) on the self-selected consumption of a fruit drink, controlling for participant gender. Based on our previous finding that texture (effect size r = 0.90) and flavour (effect size r = 0.74) of a drink (repeated measures) influenced how filling it was expected to be (McCrickerd, et al., 2012) a sample size calculation was conducted, which indicated that for the smallest effect size of interest (creamy flavour) a total of 8 participants would be needed. However, it was assumed that the effect of these expectations on self-selected intake would be smaller, therefore based on a medium effect size (r = 0.30) a second calculation suggested a sample of 44 participants (22 males and females), which was taken to 48 to counterbalance drink order across males and females.

Standard breakfast

On each test day all participants consumed a breakfast of cereal ("Crunchy Nut Cornflakes", Kelloggs, UK: males 80g, females 60g), semi-skimmed milk (Sainsbury's, UK: males 200g, females 160g) and orange juice (Sainsbury's, UK: males 200g, females 200g). The breakfast provided the males with 540 kcal (2259 KJ) and the females with 440 kcal (1841 KJ), approximately 22% of an adults daily average recommended energy intake.

Test drinks

The test drinks were based on the low energy versions of a fruit drink described in a previous study from our laboratory (McCrickerd, et al., 2012), formulated and prepared in the Ingestive Behaviour Unit at the University of Sussex. One hundred grams of the fruit drink base contained 23 kcal (96 KJ) and consisted of 31g of fresh mango, peach and papaya fruit juice (Tropicana Products, Inc.), 17g 0.1% fat fromage frais (Sainsbury's UK), 41g of water and 11g of peach flavoured diluting drink (Robinsons from Britvic, UK). The drinks were prepared in four sensory contexts varying in thick texture (thin vs. thick) and creamy flavours (low-creamy vs. high-creamy): thin/low-creamy; thin/high-creamy; thick/low-creamy; thick/high-creamy. Small quantities of tara gum (Kaly's Gastronomie, FR) were used to increase the viscosity of the drinks. The thin drinks contained 0.09g/100g of tara gum and the thick drinks 0.38g/100g. The amount of tara gum used in the drinks was based on our previous work which established that across a range of concentrations, tara gum added in these quantities produced subtle but highly perceptible differences in the viscosity without effecting the taste, pleasantness and or look of the drinks (McCrickerd, et al., 2012). Creamy flavour was enhanced by the addition of vanilla extract (Nielsen-Massey, NL: 0.33g/100g) and milk-caramel favouring (Synrise, DE: 0.16g/100g) to the high-creamy but not to the low-creamy drinks. The two physical properties attributed to creaminess were measured for the four test drinks: viscosity, which relates to perceived thickness, and lubrication, which relates to smoothness. Lubrication properties were measured at room temperature (22 °C ± 1°C) on an MTM2 tribometer (PCS Ltd. London) using a stainless steel ball and elastomer disk (see: Mills, Norton, & Bakalis, 2013) at speeds between 1 and 1500mm/s. Figures 1 and 2 show the viscosity and lubrication profiles for all four test drinks and clearly indicate that the thick drinks were more viscous and more lubricating (signified by a low traction coefficient) than the thin versions. Importantly, the creamy flavour additions did not influence the physical texture of the drinks, therefore any differences in perceived creaminess and/or intake between the high- and low- creamy flavoured drink could be attributed to the additional flavour notes, rather than actual textural properties. None of the sensory manipulations added to the caloric value of the drinks. [FIGUER 1 + 2 HERE]

Subjective appetite

Subjective measures of appetite were collected in the form of 100-point Visual Analogue Scale (VAS) ratings using the Sussex Ingestion Pattern Monitor (SIPM: Yeomans, 2000) running on a Dell PC using the windows XP professional operating system. Participants were asked "How <target> do you feel right now?" and instructed to indicate the extent to which they felt hungry, full and thirsty and their desire to eat, by dragging a marker along a 100mm scale. The scale response ranged from "Not at all <target>" (0) to "Extremely <target>" (100). These ratings were embedded amongst distracter "mood" ratings for how calm, happy, clearheaded, anxious, tired, energetic, lively and alert the participant felt. Each question was presented in a randomised order and only the appetite questions were analysed.

Sensory and hedonic evaluations of the drinks

Sensory evaluations of the drinks were also collected using the SIPM and had the same VAS format as the appetite ratings. Participants rated how thick, creamy, familiar, fruity, pleasant and sweet the drinks were, from “not at all” to “extremely”. Like the appetite questions, each rating was presented in a randomised order.

Procedure

Participants completed four test sessions in the Ingestive Behaviour Unit (“food lab”) over four non-consecutive weekdays. To begin each session, the volunteers arrived at the laboratory for their standard breakfast at a pre-arranged time between 8.30-10.00am, and were required to have consumed only water since 11.00pm the previous evening. On their first session all participants were reminded of the timings for the day’s session and of any eating and drinking restrictions. After breakfast, participants were instructed to leave the lab and return exactly two hours later having not consumed anything but water in that time or taken part in any strenuous activities.

On their return to the laboratory participants were shown to an air-conditioned testing cubicle with a PC computer where they completed the first set of appetite ratings. They were then presented with an opaque glass containing a 15g sample of a fruit drink alongside an opaque jug containing 900g of the same drink. The volunteers were instructed to taste the sample using a straw provided, hold it in their mouth while they counted to three and then swallow, a method used to ensure sufficient oro-sensory exposure to the drinks (McCrickerd, et al., 2012). Participants then evaluated the sensory and hedonic properties of the drink and once this was complete they were informed that they could drink as much of the drink as they liked by pouring from the jug provided. They were informed that if they finished the jug they would always be provided with another one. Explicit expectations generated by the drinks sensory characteristics were not assessed again in this study to reduce the potential demand effects on intake after reporting beliefs about how filling the drink was expected to be. When participants had finished consuming the drink, the glass and jug were removed and they completed a final set of appetite ratings and then took a seat in the waiting room. This part of the study took approximately 10-20 minutes to complete. The total drink left in the glass and the total amount of drink consumed and left in the glass was calculated in grams immediately after the consumption phase. Future availability of food may influence intake in the laboratory if participants plan to eat once they have completed the test session. To control for this participants remained in the laboratory waiting area for 60 minutes after they had consumed the drink, where they were free to read/work but they were not able to consume anything but water. After this time, participants returned to the testing cubicle and completed a final set of appetite ratings and a simple reaction time test where participants responded to number strings. The reaction time test was used to corroborate the study's cover story, and like the mood ratings this was not analysed.

The order of presentation of the drinks across the four sessions was counterbalanced across participants. On the final test day participants completed a short set of questions where they were asked what they thought the purpose of the study was, what was the main reason they stopped drinking in the sessions (they could give more than one reason) and whether they thought that the food and drink they received was the same over the sessions. Once complete, participants had their height (cm) and weight (kg) measured and they were thanked, debriefed and paid £30 for taking part.

Data analysis

The main outcome measures were the total amount of fruit drink consumed, the total left in the glass, changes in rated appetite and sensory judgements. Intake data from one male participant was over 3 SD from the mean, causing significant skew in these data on two out of four test days ($Z_{skew} > 0.21$, $p < 0.05$). After removal these data were normally distributed. During the debrief, a second male participant reported to have over-consumed to the point of feeling sick in their first session, and consumed less in subsequent sessions because of this. Their data was also removed. Consequently, the data from 46 participants (22 males) were included in the analysis reported. A three-way mixed

ANOVA contrasted the effect of drink thickness (thick vs. thin) and creamy flavour (low-creamy vs. high-creamy) on the total drink consumed (g) and the total drink that was left in the glass (g), with gender as the between-groups factor. Initially these analyses also included the order in which the drinks were consumed over the four sessions as a factor. However, order did not significantly affect overall intake and did not interact with the drinks sensory properties or participant gender to influence intake, therefore it was removed from the final analysis. Pearson's correlations were used to characterise the relationship between the total amount of drink consumed and participant BMI, restraint and disinhibition scores. Initial analysis indicated that pre-test hunger, fullness, thirst and desire to eat ratings were similar at the start of all of the four test sessions and were not affected by participant gender. Thus, the main appetite analysis reported was conducted on change from baseline (pre-drink) data. A series of four-way mixed ANOVAs assessed the effect of time (post-drink vs. 60 minutes later), drink texture (thick vs. thin) and creamy flavor (low-creamy vs. high-creamy) across male and female participants on hunger, fullness, thirst and desire to eat ratings. One participant did not complete the final set of appetite ratings in one session and their data are missing from this analysis (represented in reduced *df*). Finally, three-way mixed ANOVAs assessed the effect of drink thickness (thick vs. thin) and the addition of creamy flavour (low-creamy vs. high-creamy) on the sensory and hedonic ratings of the test drinks, between male and female participants. The means and SEM are presented throughout the results section and Bonferroni adjusted comparisons were used to interpret any interaction effects. Pearson's coefficients (*r*) are reported for estimates of effects sizes for all main effects comparing two groups and for any planned comparisons (Rosnow, Rosenthal, & Rubin, 2000), where 0.50 represents a large effect, 0.30 a medium effect and 0.10 a small effect.

Results

Total intake

Participants consumed less of the thick drinks compared to the thin drinks (M_{thick} = 384.6 ± 27.7g, M_{thin} = 418 ± 31.5g; $F(1,44) = 5.71$, $p = .021$, $r = 0.34$) and there was a trend for males participants to consume more than female participants overall (M_{males} = 451.5 ± 41.6 $M_{females}$ = 351.9 ± 39.8; $F(1,44) = 3.00$, $p = .090$, $r = 0.25$). However, a significant thick x gender interaction indicated that only females consumed less of the thicker drinks ($F(1,44) = 4.08$, $p = .049$, see Figure 3). Separate one-way ANOVAs for male and female participants compared the total intake of the thick and thin drinks (using a Bonferroni adjusted significance level of $p < .025$). This indicated that the male participants consumed a similar amount of the thick and thin drinks (M_{thick} = 448.9 ± 41.6g, M_{thin} = 454.2 ± 40.0g: $F(1,21) = 0.09$, $p = .767$, $r = 0.07$), while the female participants tended to drink less of the thick drinks compared to the thin versions (M_{thick} = 320.4 ± 38.2g , M_{thin} = 383.4 ± 43.6: $F(1,23) = 8.14$, $p = .009$, $r = 0.51$); a reduction of 63g. There was no effect of creamy flavour on the total drink intake ($F(1,44) = 0.45$, $p = .508$, $r = 0.10$) and thick texture and creamy flavour did not interact to influence the amount of the drink consumed ($F(1,44) < 0.01$, $p = .984$) and this was true for both male and female participants ($F(1,44) = 0.17$, $p = .681$). There was no significant relationship between the amount of drink consumed in each session and participants' BMI, restraint (TFEQ-R) or disinhibition (TFEQ-D) scores (table 1). [FIGURE 3 HERE] [TABLE 1 HERE]

Total left in the glass

At the end of the *ad libitum* consumption, participants appeared to leave slightly more of the thick drink in the glass compared to thin ones (M_{thick} = 10.2 ± 2.3g, M_{thin} = 3.8 ± 0.7g; $F(1,44) = 9.39$, $p = .004$, $r = 0.42$), probably because the increased viscosity caused a small amount of the thicker drinks to remain on the sides of the glass. There was no effect of creamy flavour ($F(1,44) = 0.00$, $p = .986$, $r < 0.01$) and no thick x creamy interaction ($F(1,44) = 1.46$, $p = .233$) on the amount of drink left in the glass after consumption and no effects of participant gender ($F(1,44) = 0.11$, $p = 0.742$, $r = 0.05$ and for all interactions with gender $p > .05$).

Changes in appetite pre- to post-drink

As expected there was a significant effect of time on all of the appetite ratings. Rated hunger ($F(1,43) = 69.24$, $p < .001$, $r = 0.79$), thirst ($F(1,43) = 28.32$, $p < .001$, $r = 0.63$) and desire to eat ($F(1,43) = 42.70$, $p < .001$, $r = 0.71$) decreased from pre- to immediately post-drink and then increased towards the pre-drink levels 60 minutes later, see table 2. This pattern was mirrored in the fullness ratings which increased immediately after consumption of the drink and then decreased 60 minutes later towards the pre-drink levels ($F(1,43) = 77.88$, $p < .001$, $r = 0.80$).

Despite differences in total intake of the drinks between male and female participants, gender did not influence the changes in hunger, fullness, thirst and desire to eat (for each effect of gender $p > .05$ and $r < 0.21$; for all interactions with time $p > .05$). Furthermore, the drink's texture and creamy flavour did not affect the changes in hunger, fullness and desire to eat (for all main effects of thick and creamy flavour, $p > .05$ and $r < 0.15$; all thick x creamy interactions and all interactions with time, $p > .05$), see table 1. However, there was a significant thick x creamy interaction for the thirst ratings ($F(1,43) = 7.09$, $p = .007$) which indicated that overall the thin/high-creamy ($M = -31.0 \pm 4.0$) and thick/low-creamy ($M = -27.8 \pm 3.9$) drinks reduced thirst more than the thin/low-creamy drink ($M = -22.7 \pm 4.0$) and thick/high-creamy drink ($M = -19.8 \pm 3.7$), however, separate repeated measures *t*-tests (using a Bonferroni adjusted significance level of $p < .008$) revealed that none of the comparisons between the drinks reached significance ($p > .018$, r > 0.23). Changes in subjective thirst over time were not affected by the drink thickness or creamy flavour (for all interactions $p > .05$). [TABLE 2 HERE]

Sensory and hedonic ratings of the drinks

The mean sensory and hedonic ratings for each of the drinks are reported in table 3. There was no effect of the thick and creamy sensory manipulations on the perceived fruitiness, sweetness, pleasantness and familiarity of the drinks (for all main effects of thick texture and creamy flavour $p >$ .05 and $r < 0.15$, and for all thick x creamy interactions $p > .05$). Perceived thickness and creaminess was affected by the sensory manipulations. The thick drinks were rated as thicker than the thin drinks ($F(1,44) = 42.34$, $p < .001$, $r = 0.70$) and there was a trend for the high-creamy drinks to be perceived as slightly thicker than the low-creamy versions ($F(1,44) = 0.34$, $p = .072$, $r = 0.27$). The low-creamy drinks were perceived to be equally creamy as the high-creamy flavoured drinks (F $(1,44) = 1.98$, $p = .166$, $r = 0.21$) but the thick drinks were rated as creamier than the thin drinks ($F(1,44) = 10.13$, $p = .003$, $r = 0.43$). Thick texture and creamy flavour did not interact to influence thick and creamy ratings ($p > .05$). Finally, there was no effect of gender on any of the sensory and hedonic ratings ($p > .05$ and $r < 0.19$ for all main effects) and no interactions ($p > .05$). [TABLE 3 HERE]

Participant feedback

Most of the participants (85%) reported that they thought the study was assessing the effects of the foods they were consuming on ‘mood’ and feelings of ‘alertness’ and ‘energy’, in line with the cover story. One participant said they had no idea what the purpose of the study was and the remaining 13% of the participants made other suggestions, such as market research for the drinks and testing the drink as an alternative to breakfast and lunch. Forty three percent of the participants reported that the most important reason they stopped drinking was because they felt full and 18 % reported that it was because they no longer felt thirsty. Only one person reported that the main reason for stopping drinking was that they had reached the bottom of the glass, and one that they had finished the bottom of the jug. Regarding the sensory differences, 54% of participants reported that the drinks were different, mostly commenting on textural differences, and 12% reported that they were different but unsure how, but 34% of the participants believed that the four drinks were the same. Interestingly, the mean intake values for those who reported that the drinks were the same across the four sessions revealed a similar pattern to the one reported in the main analysis, with female participants tending to reduce intake in response to the thick drinks (M_{thin} = 325.8 ± 52.0g, M_{thick} = 268.2 ± 41.5g), with little evidence of this in the males (M_{thin} = 577.0 ± 67.1g , M_{thick} = 576.4 ± 53.6g).

Discussion

The key finding from this study was that increasing the *perceived* thickness and creaminess of a drink reduced intake in female participants. This builds on previous work suggesting that increasing the viscosity of a drink increases the extent to which it is expected to be satiating and suggests that such expectations can influence actual eating behaviour. The majority of participants consumed all of the drink that they served themselves, indicating that the reduced intake of thicker drinks was because female participants poured out less of these versions, which is in line with research suggesting that pre-meal expectations of satiation and satiety are important determinants of meal size (Fay, et al., 2011; Wilkinson, et al., 2012). The most common reason participants reported for stopping drinking over the four sessions was feeling full and appetite ratings suggested that the participants did feel equally full after each version of the drink, despite consuming different amounts. Thus the drinks with satiety-relevant characteristics lead to a reduction in intake in female participants without affecting subjective fullness. A key question for future research would be whether sensory-related reductions in intake are compensated for in later meals.

In this study only the textural manipulation elicited a significant decrease in consumption. This builds on our previous work indicating that a subtly thicker drink was expected to be more satiating than a thinner version, with the addition of creamy flavour cues having less of an effect on these expectations (McCrickerd, et al., 2012), but contrary to our prediction the addition of creamy flavours had no impact on intake. However, *perceived* creaminess was associated with a decrease in consumption. In this study, as well as in our last, the thicker drinks were consistently rated as thicker and creamier than the thin versions. This is because perceived 'creaminess' is a complex sensory attribute, and characterised by both flavour and texture cues (de Wijk, et al., 2006; Kirkmeyer & Tepper, 2005). Human adults have consumed a range of foods and drinks in their lifetime, and with this experience, come to learn about their satiating consequences. These learned associations between a food's sensory properties and post-ingestive consequences are likely to form the basis of expectations about the how filling a food will be (Brunstrom, 2007). One possibility is that over a lifetime increased viscosity is simply a more salient predictor of nutrients in food and drinks, compared to creamy flavours alone which naturally occur in combination with changes in viscosity and lubrication. Interestingly, one third of the participants reported that they perceived no differences in the four drinks, highlighting that even though the sensory manipulations changed behaviour they were subtle enough to not always be remembered. Indeed, in the current study the four drinks were consumed across four non-consecutive days. This limits the extent to which the participants could ‘compare’ the drinks and highlights just how subtle the sensory manipulations were, with the creamy flavour additions being less noticeable than the difference in viscosity.

Why then should only the female participants alter their intake of a drink in response to its texture? Male and female participants were matched on characteristics previously thought to influence *ad libium* intake, namely BMI, dietary restraint and disinhibition, as well as reporting similar appetite sensations prior to consuming the drink (Blundell, et al., 2010; Herman & Polivy, 2008). The drinks were all equally energy-dense and the order with which males and females consumed the different drinks over the sessions did not affect intake behaviour, suggesting that differences in intake cannot be explained by nutrient learning effects. Moreover, all participants rated the drinks as similarly pleasant, sweet and familiar and both male and female participants perceived the thick drinks to be thicker and creamier than the thin versions, so it is unlikely that perceived differences in these characteristics influenced intake differentially in these groups. The decision not to re-test satiety expectations in this study was taken to reduce the potential for response bias on intake, but this means that we can only assume males and females held similar expectations that the thicker and creamier drinks would be more satiating. However, gender differences in satiety expectations based on the sensory characteristics of foods and drinks have not been previously reported (Hogenkamp, Stafleu, Mars, Brunstrom, & de Graaf, 2011; McCrickerd, et al., 2012).

An alternative explanation for the males in this study not adjusting their intake in response to the sensory manipulations is that there was another more salient influence on meal size in this group. Research investigating *ad libitum* consumption of drinks differing in viscosity reported that participants consumed less of a thicker semi-solid drink compared to a less viscous liquid version, and there was no evidence that this effect depended on the participant's gender (Zijlstra, et al., 2008). But a key difference between that and the current research is that Zijlstra and colleagues removed an important environmental cue for meal termination from their study: finishing the serving (Fay, et al., 2011). In the present study males consumed on average 451g of the drinks; this was 100g more than female participants and almost exactly the same amount as the capacity of the glass (450-470g depending on whether it was filled completely to the brim or just below). This suggests that for many of the male participants, their desired portion size was probably greater than the maximum amount of drink that could be held in the glass, and in order to consume this amount they had to pour a second helping of the drink. Perhaps this portion size cue limited the influence of satiety expectations on self-selection in the male participants more than the female participants, whose average serving size was much less than the capacity of the glass. To increase the sensitivity of the study design, we would need to provide participants with a big enough glass to reduce this bias. However, decanting a portion of a drink from a larger container is arguably more applicable to real consumer behaviour and perhaps what the current study actually demonstrates is the subtlety with which satiety expectations are likely to influence real life portion size decisions in the face of other salient serving size cues and portion norms.

Conclusion

This study indicates that increasing the perceived thickness and creaminess of a drink, by subtly increasing its viscosity, led female participants to consume less of the drink but feel no less satisfied, lending support to the idea that a food's sensory characteristics generate expectations of satiation and satiety that can guide eating behaviours. An unexpected outcome was that the sensory characteristics of the drink did not influence intake in the male participants, despite previous research suggesting that both males and females expected a thicker drink to be more satiating. This highlights that multiple external factors are likely to influence meal size selection and consumption not just in solid foods, but drinks too

Abbreviations

mPa·s: millipascal-second; s^{-1}: reciprocal seconds; mm·s^{-1}: millimetres per second MTM2: Mini-Traction-Machine tribometer.

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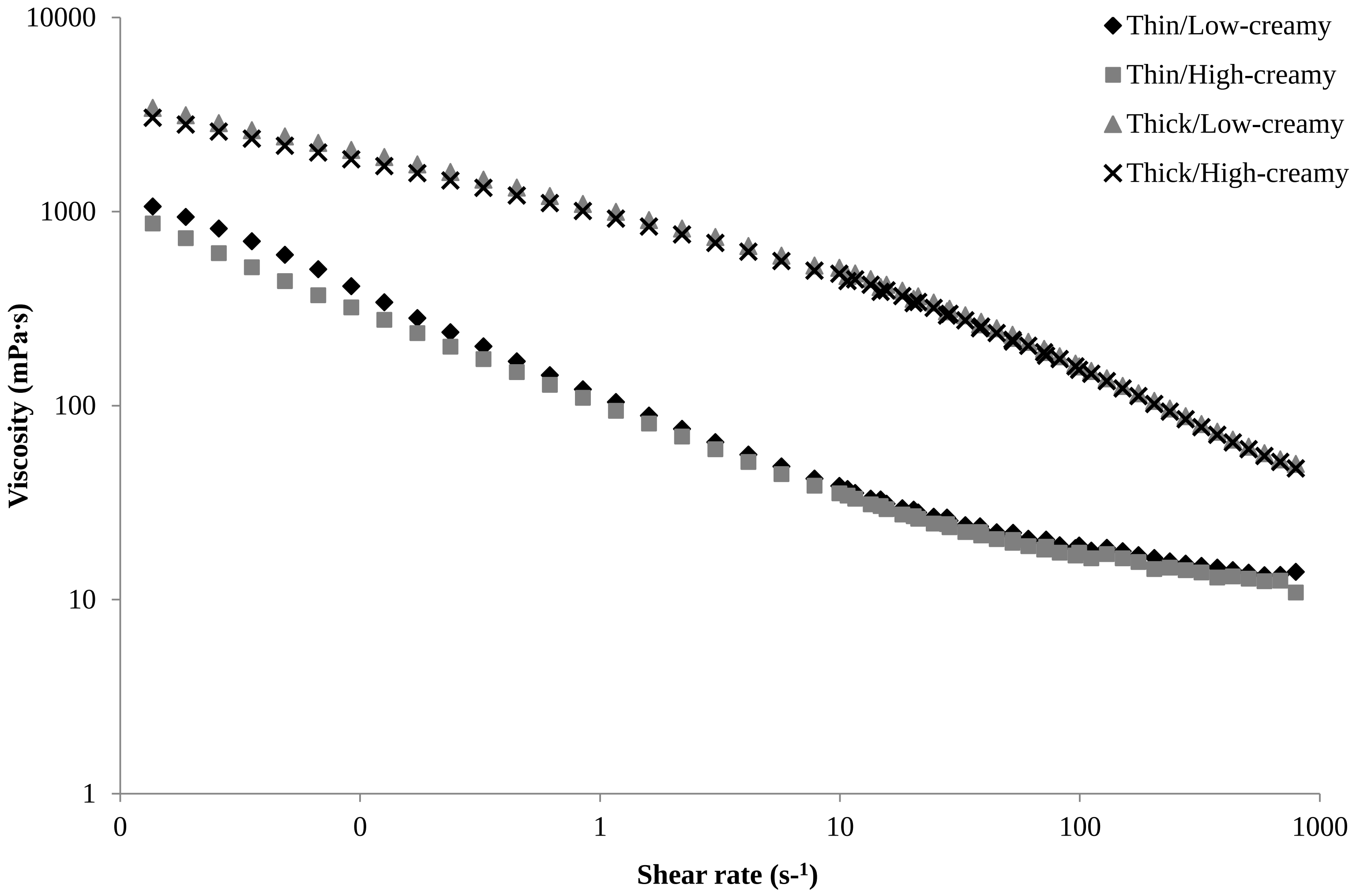
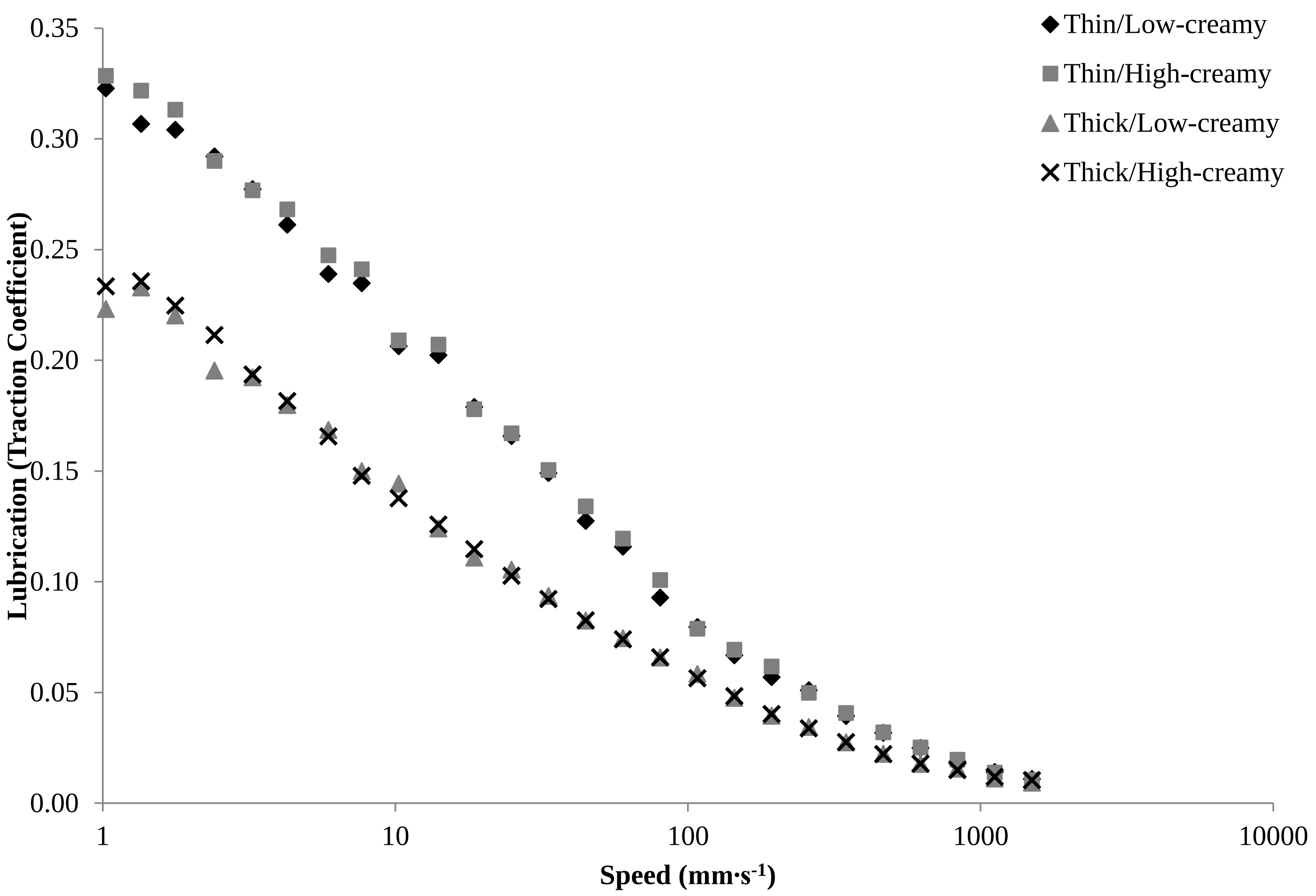
Figure 1. The viscosity of the four test drinks in millipascal-seconds (mPa·s) measured under shear, where a shear rate of between 10-100 s-1 are thought to best represent in-mouth viscosity.

Figure 2. The lubricating properties of the four test drinks measured as a traction coefficient, where a lower traction coefficient represents a more lubricating sample.

Figure 3. The total amount (g) of fruit drink consumed by male and female participants across the four sensory contexts. Error bars are based on SEM. Male participants consumed a similar amount of drink across the four sessions (p = .767), while female participants consumed less of the two thick drinks (high- and low-creamy) compared to the two thin versions (high- and low-creamy; p = .009).


10000
1000
100
10
1
Viscosity (mPa·s)
0
0
1
10
100
1000
Shear rate (s-1)
Thin/Low-creamy
Thin/High-creamy
Thick/Low-creamy
Thick/High-creamy


Thin/Low-creamy
Thin/High-creamy
Thick/Low-creamy
Thick/High-creamy
Lubrication (Traction Coefficient)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1
10
100
1000
10000
Speed (mm·s-1)

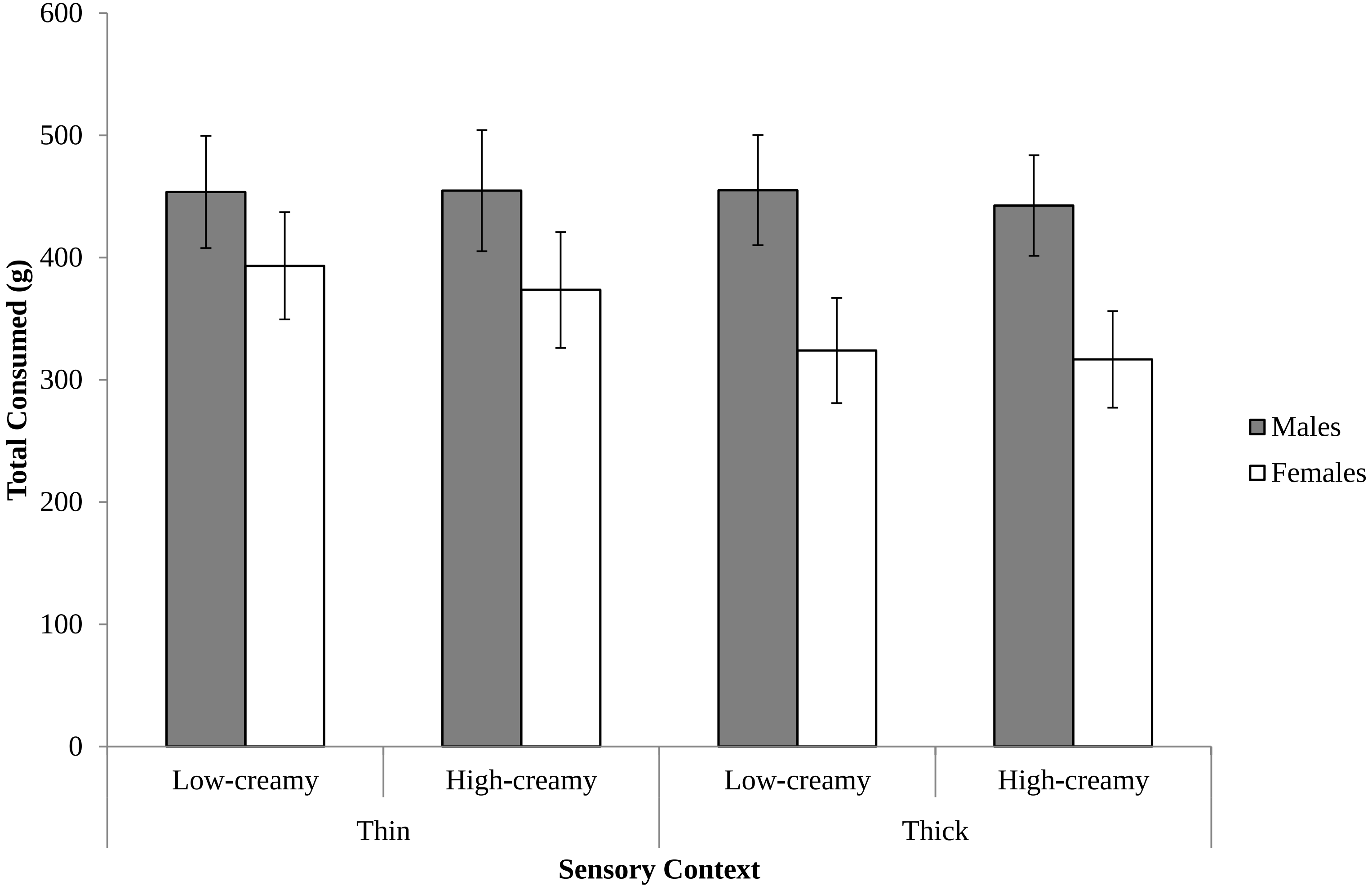

600
500
400
300
200
100
0
Total Consumed (g)
Males
Females
Low-creamy
High-creamy
Low-creamy
High-creamy
Thin
Thick
Sensory Context

Table 1. Pearson's correlations (*r*) between total intake of each drink BMI, TFEQ Restraint (R) and TFEQ Disinhibition (D) scores, for male and female participants.

		Thin		Thick	
		Low-creamy	**High-creamy**	**Low-creamy**	**High-creamy**
BMI	Males	0.25 *ns*	0.34 *ns*	0.35 *ns*	0.14 *ns*
	Females	0.28 *ns*	0.17 *ns*	0.13 *ns*	0.10 *ns*
TFEQ-R	Males	-0.16 *ns*	-0.18 *ns*	-0.31 *ns*	< -0.01 *ns*
	Females	0.15 *ns*	-0.14 *ns*	0.14 *ns*	0.25 *ns*
TFEQ-D	Males	0.23 *ns*	0.13 *ns*	0.24 *ns*	0.08 *ns*
	Females	0.32 *ns*	0.26 *ns*	<0.01 *ns*	0.10 *ns*

NS = $p > .05$

Table 2. Changes from baseline ratings of fullness, hunger, desire to eat and thirst for male and female participants across each of the drinks consumed, immediately after consumption (post-drink) and 60 minutes later. Numbers represent the mean (± SEM) VAS rating (where 0 = not at all, 100 = extremely).

		Thin				**Thick**			
		Low-Creamy		**High-Creamy**		**Low-Creamy**		**High-Creamy**	
		Post-drink	**60 min**	**Post-drink**	**60 min**	**Post-drink**	**60 min**	**Post-drink**	**60 min**
Fullness	Males	22.9±5.5	8.7±5.0	23.4±6.1	7.6±5.1	25.0±5.0	7.6±6.0	22.8±5.0	11.5±5.7
	Females	25.0±5.2	9.7±4.8	30.8±5.8	9.6±4.9	25.5±4.8	12.5±5.7	20.6±4.5	-0.1±5.4
Hunger	Males	-12.5±4.9	-4.6±5.5	-16.0±5.3	-0.8±5.1	-19.9±5.9	-3.9±7.2	-17.3±5.2	-10.2±6.8
	Females	-20.7±4.7	-9.0±5.2	-25.0±5.2	-3.7±4.9	-19.5±5.7	-4.5±6.9	-22.6±5.1	-1.3±6.5
Desire	Males	-12.7±5.9	-4.2±5.6	-12.3±5.1	-1.5±5.4	-19.6±5.0	-3.0±6.9	-17.4±6.1	-9.9±7.7
	Females	-18.6±5.6	-2.9±5.3	-23.4±4.9	-1.1±5.1	-18.1±4.7	-1.3±6.6	-17.5±5.8	-4.7±7.3
Thirst	Males	-26.8±6.2	-18.0±6.2	-25.0±6.1	-20.4±6.0	-29.7±6.3	-17.1±5.6	-20.8±6.4	-14.3±5.0
	Females	-29.6±5.9	-16.4±5.9	-42.8±5.8	-34.2±5.7	-37.0±6.0	-26.8±5.4	-26.8±6.1	-17.0±4.8

Table 3. Sensory and hedonic evaluations of the test drinks. Numbers represent the mean (± SEM) VAS rating (where 0 = not at all, 100 = extremely).

	Thin		**Thick**		***p*-value**
	Low-creamy	**High-creamy**	**Low-creamy**	**High-creamy**	
Thick	44.4 ± 3.0[a]	48.3 ± 3.0[a]	60.9 ± 2.7[b]	64.1 ± 2.8[b]	< 0.001
Creamy	53.5 ± 3.3[a]	56.1 ± 3.1[a]	60.9 ± 3.2[b]	64.0 ± 3.2[b]	0.003
Fruity	65.5 ± 2.4	64.4 ± 2.7	63.9 ± 2.4	64.9 ± 2.4	*ns*
Sweet	65.0 ± 2.9	64.9 ± 2.6	63.5 ± 2.7	64.4 ± 2.5	*ns*
Pleasant	68.7 ± 3.1	70.6 ± 2.3	69.9 ± 2.9	70.5 ± 2.5	*ns*
Familiar	61.1 ± 4.2	64.1 ± 3.6	68.4 ± 3.0	63.4 ± 3.9	*ns*

For each set of ratings *ns* represents non-significant at $p > 0.05$. Within the same rating, values marked with different letters were statistically different ($p < 0.05$) whereas those with the same letters were statistically similar ($p > 0.05$), determined using Bonferroni corrected comparisons.