View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Bournemouth University Research Online

Title: ENERGY COMPENSATION IN THE REAL WORLD: GOOD COMPENSATION FOR SMALL PORTIONS OF CHOCOLATE AND BISCUITS OVER SHORT TIME PERIODS IN COMPLICIT CONSUMERS USING COMMERCIALLY AVAILABLE FOODS

Authors: Katherine M Appleton[1,2*], Pascal P McKeown[3], Jayne V Woodside[3]

Affiliation: [1]School of Psychology, Queen's University, Belfast, Belfast, UK.

[2]Department of Psychology, Bournemouth University, Dorset, UK.

[3]School of Medicine, Dentistry and BioMedical Sciences, Queen's University, Belfast, Belfast, UK.

***Address for Correspondence:**

Katherine Appleton, Department of Psychology, Bournemouth University, Poole House, Fern Barrow, Poole, Dorset, BH12 5BB. UK. Tel: +44 (0)1202 965985. Fax: +44 (0)1202 965314. Email: k.appleton@bournemouth.ac.uk

Key words: energy compensation, energy intake, dark chocolate, hunger, cognitions, appetite

ABSTRACT

While investigations using covert food manipulations tend to suggest that individuals are poor at adjusting for previous energy intake, in the real world adults rarely consume foods of which they are ill-informed. This study investigated the impact in fully complicit consumers of consuming commercially available dark chocolate, milk chocolate, sweet biscuits and fruit bars on subsequent appetite. Using a repeated measures design, participants received four small portions (4 x 10-11g) of either dark chocolate, milk chocolate, sweet biscuits, fruit bars or no food throughout five separate study days (counterbalanced in order), and test meal intake, hunger, liking and acceptability were measured. Participants consumed significantly less at lunch following dark chocolate, milk chocolate and sweet biscuits compared to no food (smallest $t(19)=2.47$, $p=0.02$), demonstrating good energy compensation (269-334%). No effects were found for fruit bars ($t(19)=1.76$, $p=0.09$), in evening meal intakes ($F(4,72)=0.62$, $p=0.65$) or in total intake (lunch + evening meal + food portions) ($F(4,72)=0.40$, $p=0.69$). No differences between conditions were found in measures of hunger (largest $F(4,76)=1.26$, $p=0.29$), but fruit bars were significantly less familiar than all other foods (smallest $t(19)=3.14$, $p=0.01$). These findings demonstrate good compensation over the short term for small portions of familiar foods in complicit consumers. Findings are most plausibly explained as a result of participant awareness and cognitions, although the nature of these cognitions can not be discerned from this study. These findings however, also suggest that covert manipulations may have limited transfer to real world scenarios.

INTRODUCTION

Appetite is commonly investigated using covert manipulations, with the deliberate intention that participants remain as unaware as possible of any differences between different manipulations (e.g. Almiron-Roig, Palla, Guest, et al, 2013; Blundell, de Graaf, Hulshof, et al, 2010). While clearly valuable and necessary for the investigation of physiological effects (Blundell et al, 2010), consumers in the real world do not only consume in response to their physiology (Blundell et al, 2010), and are rarely faced with foods about which they know nothing, or about which the information they have might be grossly incorrect.

Studies using covert manipulations of energy content typically demonstrate poor adjustment for previous energy intake at subsequent time points (see Almiron-Roig et al, 2013; Blundell et al, 2010). Limited studies however, also demonstrate better compensation where consumers are informed of the foods they are consuming (overt manipulations) compared to uninformed (Roberto, Larsen, Agnew, Baik & Brownwell, 2010; Shide & Rolls, 1995).

Using foods with which they are familiar, individuals in the real world thus, may be more able to adjust their energy intake appropriately than is suggested by studies using covert manipulations. This issue is important when transferring the results of laboratory studies into the real world, and particularly where the results of laboratory studies may deter individuals or professionals from making or following recommendations. One current example lies in the recommendations to consume dark chocolate.

The consumption of dark chocolate (high-cocoa, flavanol-rich) has recently been positively associated with health benefits, including improved endothelial function and coronary circulation (Faridi, Njike, Dutta, et al, 2008; Flammer, Hermann, Sudano, et al, 2007; Hermann,Spieker, Ruschitzka, et al, 2006; Shiina, Funabashi, Lee, et al, 2009; Vlachopoulos, Aznaouridis, Alexopoulos et al, 2005), blood pressure (Grassi, Lippi, Necozione, et al, 2005; Shiina et al, 2009; Vlachopoulos et al, 2005), insulin sensitivity (Grassi et al, 2005), and lipid profiles (Jia, Liu, Bai, et al, 2010), to result in suggestions that individuals may benefit from the daily consumption of dark chocolate at levels of 40-60g/day (e.g. Flammer et al, 2007; Hermann et al, 2006). Benefits are suggested to result from both specific flavanols and antioxidants, and from the possible synergy of multiple components as found naturally in both cocoa and chocolate (Flammer et al, 2007; Hermann et al, 2006), but until mechanisms are elucidated and/or specific components can be isolated, suggestions for health benefits focus on the consumption of dark chocolate and dark chocolate-based products as whole foods (Flammer et al, 2007; Hermann et al, 2006).

Chocolate, however, is an energy-dense, sweet, high-fat, highly pleasurable food (Dillinger, Barriga, Escarcega, et al, 2000; Hetherington, 2001), and concerns regarding negative impacts on body weight and obesity have been voiced (e.g. Golomb, Koperski & White, 2012; Zomer, Owen, Maglaino, Liew & Reid, 2012). Sweet, high-fat foods have previously been suggested to contribute disproportionately to growing increases in obesity and body weight (e.g. see Lawton, Delargy, Smith, et al, 1998; Mazlan, Horgan, Whybrow, et al, 2006), and chocolate is among the most sought after of these sweet high-fat foods (Hetherington, 2001). Chocolate is also often consumed as a snack food (ie. outside of meals) (Dillinger et al, 2000; Bes-Rastrollo, Sanchez-Villegas, Basterra-Gortari, Nunez-Cordoba, Toledo & Serrano-Martinez, 2010), and the contribution of high-fat snacks to increased energy intake and body weight has also been suggested (Mazlan et al, 2006; Bes-Rastrollo et al, 2010; de Graaf, 2006; Hill, Wyatt, Reed, et al, 2003). Repeated studies suggest that the energy content of snacks particularly, is poorly compensated for in daily energy intakes, resulting in increased cumulative intakes and increased body weights over the longer term (e.g. Mazlan et al, 2006; Bes-Rastrollo et al, 2010).

Concerns of poor energy compensation often stem from studies using covert manipulations. Individuals consuming dark chocolate in the real world however, will be very aware that they are doing so, and will be aware (or can make themselves aware) of the potential implications of chocolate consumption for their weight and health. Consuming dark chocolate in the real world thus, in full knowledge of the fact, may have much less of an impact on body weight and weight-related health than would be suggested from studies using covert manipulations. A recent epidemiological study in fact, demonstrates frequent chocolate consumption to be associated with a low, not a high body weight (Golomb et al, 2012). The demonstration of good compensation for previous consumption using a more realistic scenario may allay fears regarding the impact of recommendations to consume chocolate on body weight. This study aimed to investigate the impact of consuming dark chocolate on subsequent appetite using commercially available foods and fully complicit consumers.

METHODS

Design

The study used a repeated measures design and preloading procedure, where dark chocolate was given as a fixed preload, and appetite was subsequently measured. A preloading procedure is a commonly used and validated procedure for the study of appetite (Blundell et al, 2010). Given the research on health benefits, and on frequent consumption, 40g of dark chocolate was used, and provided to participants as four small portions (4 x 10g) for consumption throughout the day. Appetite was measured using test meal intake and subjective ratings, and effects of dark chocolate were compared to the effects on appetite of comparable small portions of similar sweet foods (milk chocolate, sweet biscuits, fruit bars), and no food.

Participants

Twenty participants (11 males, 9 females), recruited via advertisements from the staff and students of Queen's University, Belfast, took part in the study. Participants had a mean age of 33 ± 12 years, a mean measured BMI of 24.2 ± 3.3 kg/m^2, were unrestrained (scores of <1 on the Dutch Eating Behavior Questionnaire (van Strien, Frijters, Bergers & Defares, 1986)), regularly consumed three meals a day and between-meal snacks, were non-smokers, in good health, not taking any appetite influencing medications, were familiar with and not allergic to any of the foods provided in the study, and were not aware of the purpose of the study. Participants were informed that the study was investigating 'individual responses to specific foods', and were made aware that each study day would be the same with the exception that on each day they would receive 'either dark chocolate, milk chocolate, sweet biscuits, fruit bars or no food, in addition to all other foods'. The study was approved by the Research Ethics Committee of the School of Psychology, Queen's University, Belfast, and conducted in accordance with the Declaration of Helsinki (2000).

Study foods

Four study foods were provided: dark chocolate - *Lindt 70% chocolate (Lindt & Sprungli, Switzerland)* (70% cocoa); milk chocolate - *Tesco (Cheshunt, UK) chocolate flavoured cake-covering* (a UK commercially available cooking product, that resembles milk chocolate in every characteristic (look, taste, and texture), and is often used as a cheap alternative to chocolate, but remains too low in cocoa content to warrant the name 'chocolate') (6% cocoa); sweet biscuits - *Tesco (Cheshunt, UK) Rich tea biscuits,* and fruit bars – *Humzingers dried fruit bars (Sunsweet Growers Inc., Kingston-upon-Hull, UK)*. Milk chocolate and sweet biscuits were used as familiar alternative sweet foods also commonly consumed in small portions in similar situations. The milk chocolate was also intended to allow investigations due to cocoa content as a possible explanation for effects, if appropriate. Fruit bars were included as an alternative sweet food that could also be consumed in small portions in similar situations, as a healthy alternative. The use of fruit bars allowed additional comparison of foods perceived to be healthy with those more commonly perceived as unhealthy. Dark chocolate was provided in 4 x 10g (1 square) portions (daily portion: 4 squares, 40g, 870kJ) and other foods were provided in portion sizes of similar energy content (see table 1). Food portions were provided four times throughout the day at 11am (mid-morning), 13pm (after lunch), 15.30pm (mid-afternoon) and 17.30pm (after evening meal), for consumption in 5 minutes, and contributed 5 - 12% daily energy intake (mean 9 ± 2%), depending on amount consumed at other meals. The timing of the food portions was intended to be natural. The study was not intending to investigate effects of snacking behaviour, thus foods were not specifically provided as snacks. A no food condition was also used to test for effects due to consumption.

Short term appetite

Appetite was measured using test meal intake at lunch and evening meal, and subjective perceptions throughout the day. These measures are validated measures of appetite, commonly used in laboratory studies such as this (Blundell et al, 2010).

Lunch intake was measured using an *ad-libitum* test meal comprised of *Tesco (Cheshunt, UK)* pasta, *Dolmio (Dublin, Ireland)* tomato sauce and *Tesco* olive oil, combined and served hot with *Tesco (Cheshunt, UK)* medium cheddar cheese. The meal as served provided 12.0MJ., and participants were free to consume as little or as much as they wished. Evening meal intake was measured using an *ad-libitum* buffet test meal comprised of *Hovis (York, UK) Best of both* bread, *Dromona (Dromona, Ireland)* margarine, *Tesco (Cheshunt, UK)* medium cheddar cheese, *Tesco (Cheshunt, UK)* wafer thin ham, *Tesco (Cheshunt, UK)* wafer thin chicken, *Heinz (Lincs., UK)* mayonnaise, *Branston (Lincs., UK)* pickle, Iceberg lettuce, *Walkers (Dublin, Ireland)* ready salted crisps, *Spelga (Dublin, Ireland)* strawberry yoghurt, *McVities (Bradford, UK)* chocolate digestive biscuits, and sliced Granny Smith apples. The meal as served provided 12.5MJ., and participants were again free to consume as little or as much as they wished. Quantity consumed at each test meal was determined by weighing, and converted into energy consumed using manufacturer's information.

Subjective perceptions were assessed using paper and pencil 100mm visual analogue scales (VAS) of 'hunger', 'desire to eat', 'fullness', 'prospective consumption', 'thirst' and 'desire to drink'. These VAS were completed hourly or half-hourly on each study day from 11:00am – 20.30pm.

Liking for all foods was also assessed following consumption of each food portion using 100mm VAS of 'pleasantness', 'liking', 'sweetness', 'saltiness', 'familiarity', and 'satisfaction', and acceptability of each food was assessed at the end of each day, using questions asking '*how content would you be to consume this food (in various situations)?', 'how likely would you be to consume this food (in various situations)?'* and *'how likely would you be to buy this food?*'.

Procedure

All participants undertook all four conditions in the Eating Behaviour Unit, Queen's University, Belfast, on separate days, one week apart, in a counterbalanced order. A time line for each study day is given in Figure 1. Participants were asked to consume an identical breakfast on each day and not to undertake any heavy physical activity on the day before or the day of the study. Participants were required to attend the Unit at 11am for their first food portion, and for both meals, but were free to leave the Unit between these times, took food portions and ratings scales with them for consumption / completion at appropriate times, and were asked not to eat anything else in this period. Participants were also asked not to consume anything following the evening meal on each study day, but were permitted to drink as they wished. Compliance with all instructions was confirmed by all participants. All study days were identical excepting the food portions consumed.

Figure 1 about here

Analyses

Test meal intake data were analysed per time point (lunch, evening meal), as cumulative test meal intake (lunch + evening meal) and as total intake (lunch + evening meal + food portions), using repeated measures ANOVA to investigate differences between conditions. Subjective perceptions through the morning (11:00, 11:30, 12:00, 12:30 (pre-lunch)), the afternoon (13:00 (post-lunch), 13:30, 14:30, 15:30, 16:00, 16:30, 17:00 (pre-evening meal)) and the evening (17:30 (post-evening meal), 18:30, 19:30, 20:30) were investigated using repeated measures ANOVA to investigate differences between conditions over time. Liking data were analysed by ANOVA over the two time points were food portions were consumed by themselves, and acceptability data were analysed by one-way ANOVA. Complete data sets were achieved for each participant, and data were checked prior to analysis to ensure compliance with the assumptions of ANOVA. Initial analyses revealed differences between genders in measures of energy intake, and differences between conditions in baseline hunger ratings, thus gender was used as a factor in all intake analyses, and baseline hunger ratings were adjusted for in morning hunger rating analyses. Baseline hunger ratings were not adjusted for in afternoon and evening analyses due to expected and demonstrable normalisation of hunger ratings by the lunch meal. Significance was defined using $p<0.05$. Significant differences were investigated using t-tests. Data were analysed using SPSS (IBM).

RESULTS

Test Meal intake

Following one food portion, significant differences were found between conditions in lunch intake ($F(4,72)=2.85$, $p=0.03$). Participants consumed significantly less energy following dark chocolate, milk chocolate and sweet biscuits compared to the no food condition (smallest $t(19)=2.47$, $p=0.02$), and no differences were found between these three food conditions ($F(2,36)=0.13$, $p=0.88$). No differences were found between fruit bar and no food conditions ($t(19)=1.76$, $p=0.09$). Using a calculation where % energy compensation = ((energy intake in the no food condition – energy intake in each preload condition)/energy in the preload) x 100, the differences in intake reflect a compensation of 269%, 274%, 334% and 65% for the energy provided in the dark chocolate, milk chocolate, sweet biscuit and fruit bar preloads respectively.

Following three food portions, no differences were found between conditions in evening meal intake ($F(4,72)=0.62$, $p=0.65$). However, in cumulative test meal intake (lunch + evening meal), participants again consumed significantly less energy in dark chocolate, milk chocolate and sweet biscuit conditions compared to the no food condition (smallest $t(19)=2.12$, $p=0.047$). Again, no differences were found between the three food conditions ($F(2,36)=0.42$, $p=0.66$), but no differences were found between fruit bar and no food conditions ($t(19)=0.40$, $p=0.69$). These differences reflect an energy compensation of 99%, 92%, 133% and 18% for the energy provided by the three dark chocolate, milk chocolate, sweet biscuit and fruit bar preloads respectively.

When food portions were added to cumulative intakes (lunch + evening meal + food portions = total intake), no effects were found ($F(4,72)=1.78$, $p=0.14$). Energy consumed at lunch, evening meal, and from all food portions is shown in Figure 2.

Figure 2 about here

Subjective Ratings

No differences were found between conditions in morning hunger ratings after adjusting for baseline hunger ratings (largest $F(4,76)=1.26$, $p=0.29$), and no differences were found between conditions across the afternoon or evening (largest $F(4, 76)=1.83$, $p=0.13$). Consistent effects of time, as expected, were demonstrated (smallest $F(2,38)=17.11$, $p<0.01$). Subjective ratings for hunger are provided in Figure 3.

Figure 3 about here

Liking and Acceptability

No differences were also found between food portions in measures of pleasantness, liking, satisfaction and saltiness (largest $F(3,57)=1.58$, $p=0.20$), but fruit bars were rated as significantly less familiar than all other food portions (smallest $t(19)=4.08$, $p<0.01$), and milk chocolate and fruit bars were rated as significantly more sweet than dark chocolate and biscuits (smallest $t(19)=3.25$, $p<0.01$). No effects of time were found ($F(1,19)=1.58$, $p=0.23$), expecting in familiarity, where participants became more familiar with all foods with experience ($t(19)=2.52$, $p=0.02$). Participants also reported no differences between foods in how content they would be to consume them ($F(3,57)=1.65$, $p=0.19$), but reported being more likely to consume biscuits and milk chocolate than dark chocolate and fruit bars (smallest $t(19)=2.83$, $p<0.01$), and more likely to buy biscuits and milk chocolate than fruit bars (smallest $t(19)=2.26$, $p=0.04$). Subjective perceptions of all liking and acceptability ratings are provided in Table 2.

Table 2 about here

DISCUSSION

This study investigated the impact of four small portions (4 x 10g) of dark chocolate on short-term appetite, and compared these to the effects on appetite of comparable small portions of similar sweet foods and to no food. The study was undertaken using commercially available foods and consumers who were fully aware of the foods they were consuming.

Under these conditions, dark chocolate, milk chocolate, and sweet biscuits, but not fruit bars resulted in a decrease in appetite at subsequent meals, and to an extent that good compensation for previous energy intake was achieved. Effects furthermore, were comparable following dark chocolate, milk chocolate and sweet biscuits. The comparability of these findings suggests that any effects on appetite are unlikely to be unrelated to the specific contents of the foods provided. As a result of the use of commercially available foods, the three foods used here, while similar in usual use, familiarity and energy available, were notably different in cocoa and ingredient content, macronutrient composition and sensory characteristics. Cocoa has previously been suggested to impact on appetite (e.g. Dillnger et al, 2000; Simon, 2007), macronutrient content is well known to impact on appetite (e.g. Saris & Tarnopolsky, 2003; Westerterp-Plantenga & Lejeune, 2005), and sensory characteristics also have been found to impact on appetite (e.g. Appleton & Blundell, 2007; Sorensen & Astrup, 2011; Sorensen et al, 2003). While all of these characteristics may impact on appetite, however, it is unlikely that any of these differences can account for the effects found here.

Effects are also unlikely to have arisen as a result of the energy provided. The energy provided by the food portions was small, and effects on appetite of small energy loads have previously been reported (Almiron-Roig et al, 2013), but the fruit bars in this study provided similar amounts of energy, yet had much more limited effects on appetite. The consideration of the fruit bar results alongside those from the other foods suggests that the results of this study are most plausibly a result of participant awareness and related cognitions. The participants of this study were aware of the foods they were consuming on each occasion, and could easily have deliberately adjusted their later consumption to account for this. We can not distinguish between small physiological and cognitive effects in this study, but the good energy compensation for some foods in this study compared to the usual poor compensation using covert manipulations suggest that effects here are more likely to be a result from cognitive influences. The inclusion of only unrestrained eaters however, would also suggest that these cognitive influences are more implicit or unconscious cognitive influences on food intake, such as those based on prior learning, previous experience, memory and motivation (e.g. Appleton, Martins & Morgan, 2011; Benoit, Davis & Davidson, 2010; Day, Kyriazakis & Rogers, 1998; Higgs, 2005; Higgs, 2008), than the more deliberate and conscious control of food intake as achieved through dietary restraint (e.g. Johnson, Pratt & Wardle, 2012). The poor compensation following the fruit bars compared to other foods could have resulted from either the lesser familiarity with the fruit bars compared to the other foods, suggesting again a role for learning and previous experience, or could have resulted from perceptions of the fruit bars as more healthy, but we can not distinguish between these possibilities here. The fruit bar condition in this study more closely reflects the covert manipulations that also often demonstrate only poor compensation. Regardless of the specific cognitive influences responsible, the findings of this study demonstrate nicely the potential importance of cognitive influences in the real world and in real world consumption.

Cognitive influences may also have resulted in a deliberate increase in consumption in the no food condition, but it is not possible to tell from this study whether intakes were deliberately increased in the no food condition, or deliberately decreased in the food conditions. This possible impact however, does not present a limitation to the findings of this study. While use of a repeated measures design will highlight differences between conditions (Rogers, in press), individuals consuming any of the foods in this study in the real world will, of course, be able to adjust their intakes of other foods down or up as they wish. The demonstration of naturalistic behaviour was the purpose of this investigation.

Interestingly, effects were only found at lunch intake following one food portion and were not found in evening intake following a further two portions. No effects were also found in subjective ratings in the evening following all four. The absence of effects in evening meal intake and evening ratings is likely to result from the small contribution of the food portions to daily energy intake, making accurate physiological or cognitive adjustment difficult over time (see Almiron-Roig, et al, 2013; Blundell et al, 2010).

Interestingly, however, the small portions provided by the familiar foods in this study also did not increase total energy intake compared to no food. Previous work has also demonstrated a minimal impact of additional small food items on overall energy intake (Lawton et al, 1998; Johnstone, Shannon, Whybrow, Reid & Stubbs, 2000; Poston, Haddock, Pinkston, et al, 2005). The limited effects of the food portions in this study may be a result of the very specific situation in which they were consumed (i.e. in small portions, surrounded by controlled consumption, and over a single day), but the findings of this study suggest that the complicit consumption of small food items such as 10g squares of dark chocolate or 2 biscuits may be unlikely to result in overall increases in energy intake. Given the significant health benefits conferred by the consumption of dark chocolate (Faridi et al, 2008; Grassi et al, 2005; Jia et al, 2010; Shiina et al, 2009; Vlachopoulos et al, 2005), concern over potential negative health impacts as a result of increased dark chocolate consumption, thus may be unwarranted. Various other studies also suggest a beneficial role for small food items and snacks for increasing dietary variety, dependent on food type (Bellisle, Dalix, Mennen, et al, 2003; Lawton et al, 2010; Johnstone et al, 2000 Poston et al, 2005). The possibility of a cumulative effect over time as a result of the repeated consumption of small food items however can not be dismissed from this study, and it is small but repeated increases in energy intake that are frequently held responsible for weight gain (Hill et al, 2003). Energy intakes are (marginally) higher in this study in both chocolate conditions, compared to no food, and compensation is not complete in either of these conditions following repeated portions, thus repeated consumption may result in a detrimental impact on body weight over the longer term. A role for snacks particularly, in increasing the energy density and fat content of the diet and in promoting overconsumption and obesity has been suggested (Mazlan et al, 2006; Bes-Rastrollo et al, 2010; de Graaf, 2006), although recent reviews suggest minimal associations between snacking, meal frequency and body weight, when data are corrected for plausible energy intake reporting and other possible methodological errors (Leidy, Harris & Campbell, 2011; McCrory, Howarth, Roberts & Huang, 2011). Longer term studies would clearly be of interest.

Our study is limited in some respects by the differences between the foods provided as discussed. Our main outcome however was energy intake, and the difference in the energy provided by the preloads was 30kJ. across the whole day. Considering expected daily energy intakes of 8300-10500 kJ., a 30 (0.2-0.25%) kJ. difference in energy between preloads is unlikely to have significant impact. We also allowed participants to leave the laboratory between meal times, so we can not be sure that the mid-afternoon food portion, and afternoon and evening VAS measures were consumed / completed at the correct time. All participants however confirmed compliance with all instructions on each day, we have no reason to suspect any were lying, or that this likely to have been systematic across conditions. Possible violations of the procedure are thus unlikely to have resulted in any changes to our findings. We also made no attempt to investigate the physiological / cognitive influences responsible for effects. Our inclusion of unrestrained eaters in the study intended to access more implicit or unconscious cognitive influences on food intake, such as those based on prior learning, previous experience and memory, but more deliberate cognitive controls may have also been utilised. The use of unrestrained consumers is possibly a limitation of the work. The investigation of effects in restrained eaters, while potentially complicated by the addition of more deliberate cognitive control and some of the side effects of this deliberate control such as disinhibition, would clearly be of interest.

CONCLUSIONS

In conclusion, these findings suggest that the consumption of small portions of familiar sweet foods - dark chocolate, milk chocolate and sweet biscuits can be well compensated for in complicit consumers, so that consumption of these small portions compared to no food, has limited effects on appetite. Poorer compensation was found for one unfamiliar food – fruit bars. Findings are most plausibly explained as a result of participant awareness and cognitions. These findings also suggest that covert manipulations may have limited transfer to real world scenarios and that concerns regarding impacts on body weight as a result of advice to consume dark chocolate may be unwarranted. Longer term studies however, are clearly required.

ACKNOWLEDGEMENTS

This work was supported by Queen’s University, Belfast, Belfast, UK, and conducted while all authors were affiliated with Queen’s University, Belfast. Grateful thanks are extended to Nicole McKeever, Queen’s University, Belfast, for the majority of data collection.

FINANCIAL SUPPORT

This work was supported by Queen’s University, Belfast, Belfast, UK.

CONFLICTS OF INTEREST

There are no conflicts of interest.

AUTHORSHIP

All authors formulated the research question, KMA designed and ran the study, analysed all data, and wrote the manuscript. All authors contributed to interpretation of results and manuscript revision.

REFERENCES

Almiron-Roig, E., Palla, L., Guest, K., Ricchiuti, C., Vint, N., Jebb, S.A., Drewnowski, A. (2013). Factors that determine energy compensation: a systematic review of preload studies. *Nutrition Reviews, 71,* 458-73.

Appleton, K.M., Blundell, J.E. (2007). Habitual high and low consumers of artificially sweetened beverages: Effects of sweet taste and energy on short-term appetite. *Physiology & Behaviour, 92,* 479-486.

Appleton, K.M., Martins, C., Morgan, L.M. (2011). Age and experience predict accurate short-term energy compensation in adults. *Appetite, 56,* 602-606

Bellisle, F., Dalix, A.M., Mennen, L., et al. (2003). Contribution of snacks and meals in the diet of French adults: a diet-diary study. *Physiology and Behavior, 79,* 182-189.

Benoit, S.C., Davis, J.F., Davidson, T.F. (2010). Learned and cognitive controls of food intake. *Brain Research, 1350,* 71-6.

Bes-Rastrollo, M., Sanchez-Villegas, A., Basterra-Gortari, F.J., Nunez-Cordoba, J.M., Toledo, E., Serrano-Martinez, M. (2010). Prospective study of self-reported usual snacking and weight gain in a Mediterranean cohort: The SUN project. *Clinical Nutrition, 29,* 323-30.

Blundell, J., de Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluch, A., Mela, D., Salah, S., Schuring, E., van der Knaap, H., Westerterp, M. (2010). Appetite control: methodological aspects of the evaluation of foods. *Obesity Reviews, 11,* 251-270.

Day, J.E., Kyriazakis, I., Rogers, P.J. (1998). Food choice and intake: Towards a unifying framework of learning and feeding motivation. *Nutrition Research Reviews, 11,* 25-43.

De Graaf, C. (2006). Effects of snacks on energy intake: An evolutionary perspective. *Appetite, 47,* 18-23.

Dillinger, T.L., Barriga, P., Escarcega, S., et al. (2000). Food of the gods: cure for humanity? A cultural history of the medicinal and ritual use of chocolate*. Journal of Nutrition, 130,* 2057S-72S.

Faridi, Z., Njike, V.Y., Dutta, S., et al. (2008). Acute dark chocolate and cocoa ingestion and endothelial function: a randomized controlled crossover trial. *American Journal of Clinical Nutrition, 88,* 58-63.

Flammer, A.J., Hermann, F., Sudano, I., et al. (2007). Dark chocolate improves coronary vasomotion and reduces platelet reactivity. *Circulation, 116,* 2376-82.

Golomb, B.A., Koperski, S., White, H.L. (2012). Association between more frequent chocolate consumption and lower Body Mass Index. *Archives of Internal Medicine, 176,* 519-21.

Grassi, D., Lippi, C., Necozione, S., et al. (2005). Short term administration of dark chocolate is followed by a significant increase in insulin sensitivity and a decrease in blood pressure in healthy persons. *American Journal of Clinical Nutrition, 81,* 611-4.

Hermann, F., Spieker, L.E., Ruschitzka, F., et al. (2006). Dark chocolate improves endothelial and platelet function. *Heart, 92,* 119-120.

Hetherington, M.M. (2001). Chocolate: from adoration to addiction. In Hetherington, M. (ed.). Food craving and addiction. Surrey, England: Leatherhead. Pp. 295-319.

Higgs S. (2005). Memory and its role in appetite regulation. *Physiology and Behavior, 85,* 67-72.

Higgs S. (2008). Cognitive influences on food intake: The effect of manipulating memorz for recent eating. *Physiology and Behavior, 94,* 734-9.

Hill, J.O., Wyatt, H.R., Reed, G.W., et al. (2003). Obesity and the Environment: Where Do We Go from Here? *Science, 299,* 853-855.

Jia, L., Liu, X., Bai, Y.Y., et al. (2010). Short term effects of cocoa product consumption on lipid profile: a meta-analysis of randomized controlled trials. *American Journal of Clinical Nutrition, 92,* 218-25.

Johnson, F., Pratt, M., Wardle, J. (2012). Dietary restraint and self-regulation in eating behavior. *International Journal of Obesity, 36,* 665-74.

Johnstone, A.M., Shannon, E., Whybrow, S., Reid, C.A., Stubbs, R.J. (2000). Altering the temporal distribution of energy intake with isoenergetically dense foods given as snacks does not affect total energy intake in normal-weight men. *British Journal of Nutrition, 83,* 7-14

Lawton, C.L., Delargy, H.J., Smith, F.C., et al. (1998). A medium-term intervention study on the impact of high- and low-fat snacks varying in sweetness and fat content: Large shifts in daily fat intake but good compensation for daily energy intake. *British Journal of Nutrition, 80,* 149-161.

Leidy, H.J., Harris, C.T., Campbell, W.W. (2011). The effect of eating frequency on appetite control and food intake: Brief synopsis of controlled feeding studies. *Journal of Nutrition, 141,* 154S-7S.

McCrory, M.A., Howarth, N.C., Roberts, S.B., Huang, T.T.-K. (2011). Eating frequency and energy regulation in free-living adults consuming self-selected diets. *Journal of Nutrition, 141,* 148S-153S.

Mazlan, N., Horgan, G., Whybrow, S., et al. (2006). Effects of increasing increments of fat- and sugar-rich snacks in the diet on energy and macronutrient intake in lean and overweight men. *British Journal of Nutrition, 96,* 596-606.

Poston, W.S.C., Haddock, C.K., Pinkston, M.M., Pace, P., Karakoc, N.D., Reeves, R.S., Foreyt, J.P. (2005). Weight loss with meal replacement and meal replacement plus snacks: a randomized trial. *International Journal of Obesity, 29,* 1107-1114.

Roberto, C.A., Larsen, P.D., Agnew, H., Baik, J., Brownell, K.D. (2010). Evaluating the impact of menu labelling on food choices and intake. *American Journal of Public Health, 100,* 312-8.

Rogers, P.J. (in press). Measuring satiety effects: study design makes a difference to the results. *Appetite.*

Saris, W.H., Tarnopolsky, M.A. (2003). Controlling food intake and energy balance: which macronutrient should we select? *Curr Opinions in Clinical Nutr Metab Care 6,* 609-13

Shide, D.J., Rolls, B.J. (1995). Information about the fat content of preloads influences energy intake in healthy women. *Journal of the American Dietetic Association, 95,* 993-8.

Shiina, Y., Funabashi, N., Lee, K., et al. (2009). Acute effect of oral flavanoid-rich dark chocolate chocolate intake on coronary circulation, as compared with non-flavanoid white chocolate, by transthoracic Doppler echocardiography in health adults. *International Journal of Cardiology, 131,* 424-9.

Simon, H.B. (2007). I've been called a "chocoholic" because I love chocolate and eat a piece after dinner every night. My weight is fine and my cholesterol is, too. Is there any reason to change my ways?. *Harvard Mens Health Watch, 12,* 7-8.

Sorensen, L.B., Astrup, A. (2011). Eating dark and milk chocolate: a randomized crossover study of effects on appetite and energy intake. *Nutrition and Diabetes, 1,* e21.

Sorensen, L.B., Moller, P., Flint, A., Martens, M., Raben, A. (2003). Effect of sensory perception of foods on appetite and food intake: A review of studies on humans. *International Journal of Obesity, 27,* 1152-66.

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

Vlachopoulos, C., Aznaouridis, K., Alexopoulos, N., et al. (2005). Effect of dark chocolate on arterial function in healthy individuals. *American Journal of Hypertension, 18,* 785-91.

Westerterp-Plantenga, M.S., Lejeune, M.P. (2005). Protein intake and body weight regulation. *Appetite, 45,* 187-90.

Zomer, E., Owen, A., Maglaino, D.J., Liew, D., Reid, C.M. (2012) The effectiveness and cost effectiveness of dark chocolate consumption as prevention therapy in people at high risk of cardiovascular disease: best case scenario using a Markov model. *British Medical Journal, 344,* e3657.

Figure Legends

Figure 1: Time line for each study day

Figure 2: Mean and std. error energy (kJ.) consumed at lunch, evening meal and from all food portions by all participants (N=20) in all five study conditions

Figure 3: Hunger ratings across the day for all participants (N=20) in all four study conditions. Ratings following dark chocolate are represented by diamonds, milk chocolate by squares, sweet biscuits by triangles; fruit bars by crosses, and no food by stars.

Table 1: Preloads provided per small portion and per day in quantity, weight (g) and energy (kJ.) in all four study conditions

Preload	Dark chocolate	Milk chocolate	Sweet biscuits	Fruit bars	No food
Single portion	1 square	$1\ ^{2}/_{3}$ squares	$2\ ^{1}/_{4}$ biscuits	$1\ ^{1}/_{4}$ bars	-
Daily portion	4 squares	7 squares	9 biscuits	5 bars	-
Weight provided / day (g)	40	44	45	75	0
Energy provided / day (kJ)	870	903	887	874	0
Carbohydrate (g/100g)	34	52	73	0	0
Of which, sugars (g/100g)	29	48	21	0	0
Fat (g/100g)	41	31	14	0	0
Protein (g/100g)	9.5	2.9	7.2	0	0

Table 2: Mean (st. dev.) liking and acceptability ratings for all preload foods.

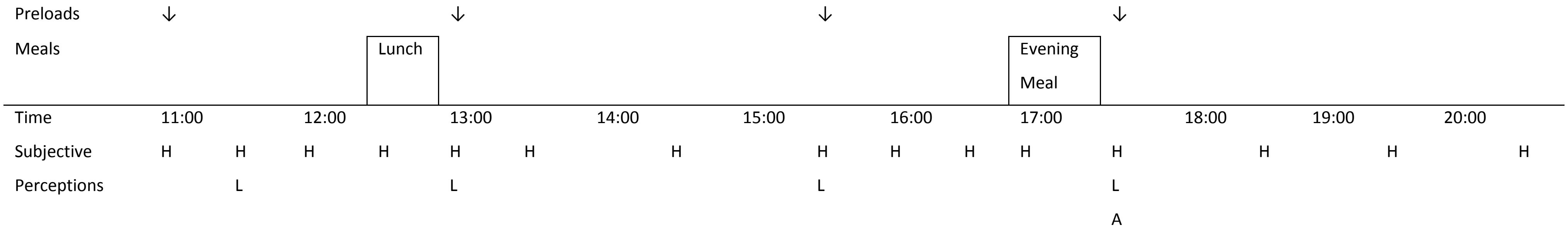
Rating	Dark chocolate	Milk chocolate	Sweet Biscuits	Fruit bars
Pleasantness (mm)[1]	60 (34)	58 (35)	65 (24)	57 (32)
Liking (mm)[1]	60 (32)	58 (36)	67 (23)	57 (33)
Sweetness (mm)[1]	49 (31)[a]	81 (19)[b]	57 (19)[a]	73 (16)[b]
Saltiness (mm)[1]	14 (11)	13 (19)	16 (18)	8 (10)
Familiarity (mm)[1]	63 (30)[a]	74 (22)[a]	76 (25)[a]	33 (25)[b]
Satisfaction (mm)[1]	55 (29)	48 (32)	57 (21)	49 (27)
Content to consume (mm)[2]	67 (32)	76 (28)	75 (20)	58 (35)
Likely to consume (mm)[2]	46 (37)[a]	61 (31)[c]	62 (30)[b]	31 (31)[ad]
Likely to buy (mm)	42 (35)	61 (34)[b]	50 (33)[b]	32 (32)[a]

[1]Liking ratings are combined over two time points, where food portions were consumed alone.

[2]Acceptability ratings are combined over three questions based on different situations.

[ab]Significant differences ($p<0.05$) within row between letter pairs a/b, c/d.

Figure 1: Time line for each study day



H – hunger ratings; L – liking ratings; A – acceptability ratings

Figure 2: Mean and std. error energy (kJ.) consumed at lunch, evening meal and from all food portions by all participants (N=20) in all five study conditions.

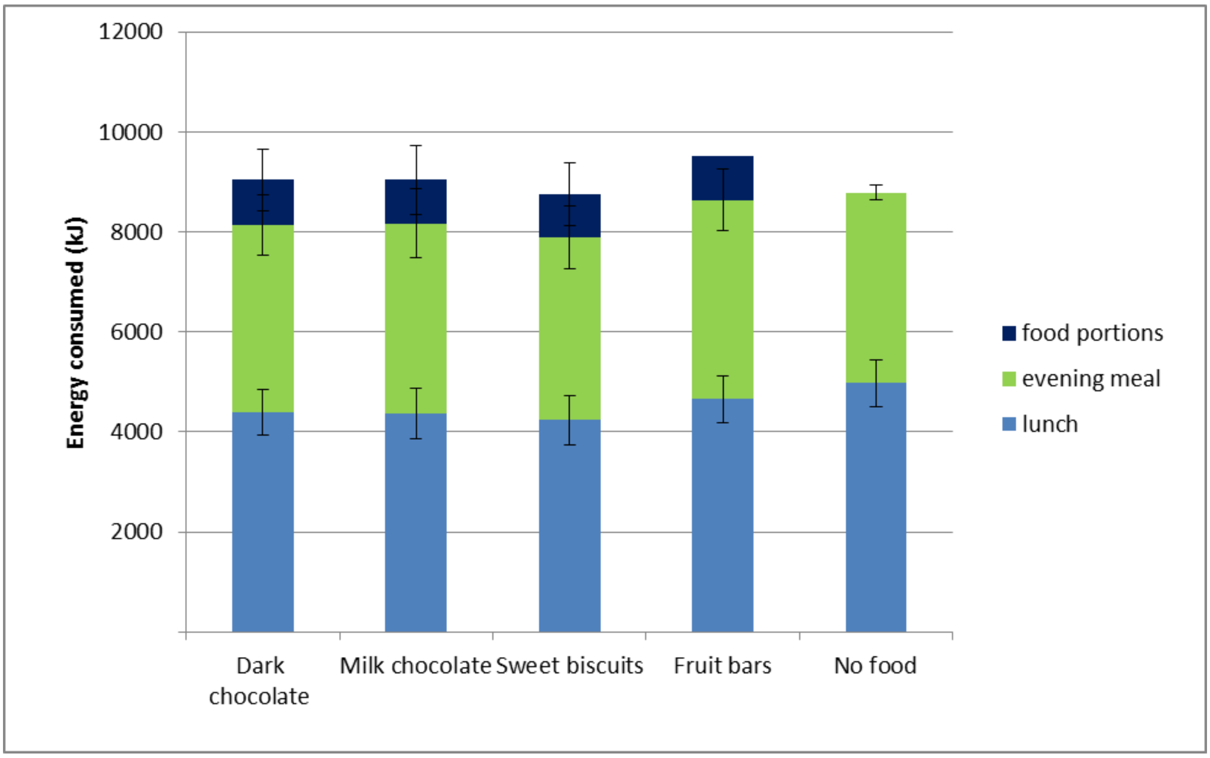


Figure 3: Hunger ratings across the day for all participants (N=20) in all four study conditions. Ratings following dark chocolate are represented by diamonds, milk chocolate by squares, sweet biscuits by triangles; fruit bars by crosses, and no food by stars.