ORIGINAL ARTICLE

How does plate size affect estimated satiation and intake for individuals in normal-weight and overweight groups?

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Summary

Objective

Manipulating plate sizes could possibly introduce perceptual biases for judging food satiation and intake, which is thought to be related to the Delbeouf illusion – a visual illusion based on the perceived size of one object related to another. This study was to investigate whether an association exists between an individual's susceptibility to the plate-size-effect and their weight status (i.e. normal-weight versus overweight).

Methods

The study assessed the effect of plate size amongst normal-weight (N = 124) and overweight (N = 79) New Zealand Europeans. All participants were asked to rate estimated satiation (ES) and intake (EI) on Visual Analogue Scales for 20 food images, which comprised photographs of ten different dishes placed on large versus small plates. These responses were analysed by mixed-model ANCOVA.

Results

The results showed that the plate size had significant effects on ES ($F_{(1, 1986)}$ = 19.14, $p < 0.001$) and EI ($F_{(1,1986)}$ = 5.25; p = 0.048), with the small plate associated with higher ES and lower EI than the large plate. Significant differences in ES and EI were also evident across the weight groups (ES: $F_{(1,1986)}$ = 4.26, p = 0.039; EI: $F_{(1,1986)}$ = 42.22, $p < 0.001$), with the normal-weight group reported higher ES and lower EI than the overweight group. Furthermore, the weight group and the plate-size-effect were found to be involved in a significant interaction for EI. Post-hoc tests showed that the plate size only had a significant effect for the normal-weight group ($p < 0.05$), but not for the overweight group.

Conclusions

Overall, the study demonstrated that the normal-weight and overweight group differed in their susceptibilities to the plate-size-effect (reflected by EI). This study revealed some potential moderators for the plate-size-effect, such as the type of dish, and its associated appeal and familiarity, and provided useful indications about the effectiveness of small plates for food reduction.

Keywords: Eating behaviour, expected satiation, plate size, weight status.

Introduction

Overconsumption of food has become a common phenomenon in many modern societies, where foods are increasingly accessible, diverse and palatable (1). An increasing amount of research has suggested that perceptual factors are important for regulating food consumption (2–4). Identifying these perceptual factors represents an important research question in the current rapid-changing food environment.

Decisions on portion size largely depend on perception of food volume (5,6), which can be measured by the estimated satiation (ES) or estimated intake (EI) of the food. Defined by Brunstrom and Rogers (5), ES is the

relative feeling of fullness to be expected after consuming different foods when compared on a calorie-for-calorie basis, which is acquired by a learned association between sensory properties of food and their abilities to promote satiation. EI is referred to as estimated consumption volume of food (7). Conceivably, an inverted relationship is expected between ES and EI. While it has been previously suggested that people are extremely adept at estimating these entities (2), individual's estimation can be susceptible to environmental factors. For instance, the context of eating, such as restaurant versus laboratory setting, could alter people's intake (8,9).

In particular, factors like the size and weight of utensils or containers could have impacts on individual's judgements of food portions (10). People tend to underestimate the quantity of food when it is presented on a large plate, or conversely overestimate the quantity when it is presented on a small plate (11–13). This bias has been explained by Van Ittersum and Wansink (14) by the Delboeuf illusion – when the perceptual of object size changes based on the surrounding context. In the context of food consumption, a small difference between the plate area and the food area increases the perception of food volume, and correspondingly leads to enhanced ES and diminished EI. This effect is herein referred to as the plate-size-effect.

The plate-size-effect was not shown to have direct effects on reduction of food intake. Many studies therefore disputed the effectiveness of using small plates for food reduction (15–17). Robinson and others (18) in their systematic review reported that three out of the nine studies found significant relationships between plate size and intake volume, five showed no difference and one found mixed results. Similarly, Libotte and others (19) in a separate review also concluded that the available data on the relationship between plate size and intake were contradictory. As a result, potential benefits of using small dishware to reduce food intake have yet to receive widespread support (18,20). These contradictory evidence also suggested further factors to be identified for understanding the plate-size-effect.

Aside from environmental factors, characteristics of individuals, such as gender, age and body mass index, have been shown to be influential on behaviours relating to food portion judgements (2,21–24). Conceivably, these individual characteristics could also be important in determining the individual's susceptibility to the plate-size-effect. Of many possible individual characteristics, body weight is of particular interest and relevance. However, only a few studies have specifically discussed the plate-size-effect with respect to weight status, which yielded some unexpected findings. Shah and others (25) found that plate size had no effect on overweight group or normal-weight group, contradictory to some other studies on lean participants. In addition, Yip and others (26) assessed effects of plate size on overweight, unrestraint female eaters, and also concluded no effect due to plate size. These authors suspected that the *ad libitum* design contributed to these unexpected results.

In light of the relatively few studies conducted and the inconsistent findings, the present study was to test individual's susceptibility to the Delbeouf illusion with food images, by asking participants to rate ES and EI on food placed on large and small plates. Specifically, the study was to test for the hypothesis that a potential association exists between an individual's susceptibility to the plate-size-effect and their weight status (i.e. normal-weight versus overweight).

Methods

Participants

All participants in this study were New Zealand Europeans between the age of 18 and 35 years, healthy and mostly university students. The recruitment for participants was done through university websites, student associations, social media and participant database from previous studies. Potential participants were provided participant information sheets and asked to give written consents prior to the study. People in any BMI range were invited to participate in this study, although the subsequent data analyses were only performed on the participants whose BMI was within the specified intervals (normal weight: 18.5–24.9 kg m^{-2}; overweight: 25.0–29.9 kg m^{-2}). Originally, 456 individuals opened the questionnaire link, of which responses from 203 were considered acceptable according to the pre-determined data checking protocol, yielding an overall completion rate was 44.5%.

Of the participants, 79 were grouped into the overweight group (22 males; BMI: 27.25 ± 1.4 kg m^{-2}; Age: 24.1 ± 3.4 years), and 124 were grouped into the normal-weight group mean (28 males; mean BMI: 22.21 ± 1.9 kg m^{-2}; age: 23.8 ± 2.8 years). Ethical approval for this study was obtained from the University of Otago Human Ethics Committee (16/01B).

Questionnaire design

In order to obtain food images to be used in the questionnaire, ten different dishes were made. These particular ten dishes were selected for based on a preliminary questionnaire study. Six postgraduate

students were shown recipes of 20 dishes and asked to rate their levels of liking and familiarity for each dish on a scale. Based on their responses, these ten dishes were selected to represent a wide range of hedonic and familiarity values. All of these dishes contained energy levels within a range of 375–440 kcal, with balanced sources of protein, fibre and carbohydrates. Each dish was photographed twice on a 23-cm-diameter plate and a 27-cm-diameter plate. Care was taken when transferring the food from one plate to another, in order to minimize variation in the presentation. The food was ensured to be mounted to a certain height. These photographs were taken under a constant lighting condition (Canon SX50 HS, 180 dpi). All photos included cutlery (a knife and fork set or a pair of chopsticks depending on the ethnic origin of the dish), and a standard 355-ml drink can serve as visual references of the size of the dish (see examples in Figure 1). For each photograph, the food area on the plate was measured three times by image measurement software (Klonk, Image Measurement Corporation, USA), the average of which was recorded for computing the Food/Plate ratio. Consistently across all dishes, the small plates are associated with higher Food/Plate ratios than the large plates. Details about the dishes and photographs are in Table 1.

Figure 1 Examples of photographs of the same dish on the large plate (A; 27-cm diameter) and the small plate (B; 23-cm diameter). Aside from the plates, sizes of other components are constant. Respondents were specifically instructed not to consider the can of drink in their responses.

Table 1 Information of each of the ten meals, along with the ratio of the food area to the plate area

Name	Code	Energy (kcal)	Weight (g)	Food/Plate ratio 27-cm plate	Food/Plate ratio 23-cm plate
Chicken Caesar Salad	0	398.4	346.0	0.53	0.74
Dumplings	1	378.8	168.4	0.31	0.43
Beef Stir fry	2	406.2	321.2	0.35	0.49
Fish Linguine	3	407.6	257.1	0.32	0.45
Chicken Fried Rice	4	374.6	262.3	0.46	0.64
Korean Beef Plate	5	379.0	337.2	0.48	0.66
Lamb and Potato	6	377.8	301.2	0.41	0.56
Meatballs and Potato	7	436.3	337.6	0.32	0.45
Teriyaki Chicken	8	374.4	265.9	0.32	0.45
Mushroom Risotto	9	421.8	148.2	0.32	0.44

The questionnaire was delivered in a form of questionnaire, which was developed and distributed using Qualtrics© (2016). The questionnaire consisted of questions presented to each participant in a randomized order. With each image presentation, the participant was asked to respond, on a 100-point Visual Analogue Scale (VAS), to the question 'How full will you be after consuming the entire dish?' with the end points anchored with 'not full at all' and 'extremely full'; and the question 'As your main meal of the day, what portion of the plate would you usually consume?' with the end points anchored with 'none' and 'all of the food'. For the present study, the response to the former question is referred to as ES; the response to the latter question is referred to as EI. The participants were also required to rate Liking and Familiarity of each dish on similar line scales, with the right-hand-end anchored with 'not at all' and the left-hand-end anchored with 'extremely like (or familiar)'. At the end of the questionnaire, the participants were asked to report their weight (in kg) and height (in cm). In order to minimize false reporting, an option of 'prefer not to say' was available.

Data analysis

First, a univariate analysis of variance (ANOVA) was performed on the dataset of liking and familiarity, respectively, to assess differences across the dishes and the BMI groups. Subsequently, a mixed-model univariate analysis of covariance (ANCOVA) was applied to data of ES and EI to assess effects of plate size on people of separate weight groups, controlling for liking and familiarity of the food presented. With this model, Plate Size was defined as the within-subjects factor; BMI Group and Gender were the between-subjects factors; ratings for liking and familiarity of each dish were the covariates. Any dataset that violated the assumption of sphericity was corrected using *Greenhouse–Geisser* corrections. Simple tests with Bonferroni corrections

were employed as post-hoc tests where appropriate to disentangle higher-order effects. All data analyses were performed using SPSS (23.0; IBM®).

Results

The ANOVA on the liking and familiarity ratings suggested significant differences across the dishes (liking: $F_{(9,1998)} = 16.66$, $p < 0.001$; familiarity: $F_{(9,1998)} = 14.36$, $p < 0.001$), but not between the BMI groups.

The mixed-model ANCOVA on ES revealed a significant main effect of the Plate Size ($F_{(1, 1986)} = 19.14$, $p < 0.001$). On average, the ES rating associated with the large plate (M = 80.13; SE = 0.355) was significantly lower than that associated with small plate (M = 86.83; SE = 0.320). Furthermore, the BMI group was also found to have a significant effect on the ES rating. Specifically, the normal-weight group gave a slightly but significantly higher ES rating (M = 84.08; SE = 0.368) compared to the overweight group (M = 82.88; SE = 0.454; $F_{(1,1986)} = 4.26$, $p = 0.039$). The results also showed that these ten dishes were given significantly different ES ratings ($F_{(9,1986)} = 51.14$, $p < 0.001$), despite having similar caloric values. Figure 2 (Panel A) displays the averaged ES rating for each of the ten dishes. In comparison, Dish 0 and 7 were associated with lower ratings.

Interestingly, no significant interaction was evident between the Plate Size and BMI Group ($p > .05$; see Table 2), implying little difference in the ES between the large and small plate across the normal-weight and overweight group. A significant interaction effect on the ES was observed for the Plate Size and Dish ($F_{(9,1986)} = 6.85$, $p < 0.001$), suggesting the difference in ES across the plate size was dependent of the type of dish. This result was further explained by the significant interaction effect between the Plate Size and the
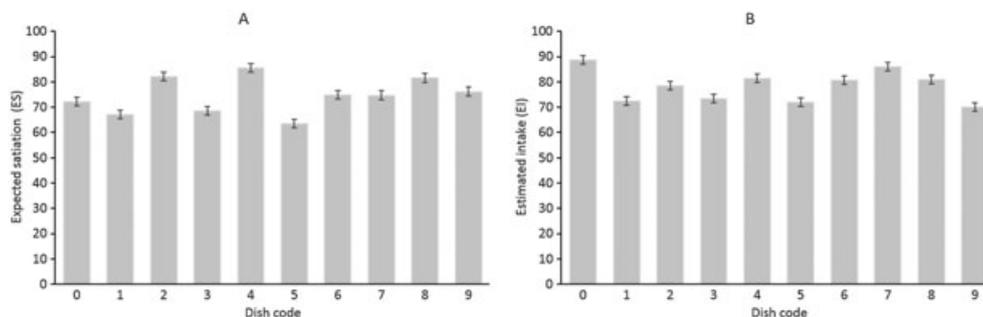

Figure 2 Bar graphs of the means (with standard errors) of the ES (A) and EI (B), across all individuals and plate sizes, for the ten types of dishes used in the present study.

Table 2 Means and standard errors (SE) of the estimated satiation and intake by the normal-weight and overweight group, respectively

| | Estimated satiation | | | | Estimated intake | | | |
| | Large plate | | Small plate | | Large plate | | Small plate | |
Weight group	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Normal weight	81.67	1.28	85.89	1.25	85.70	0.82	80.37	1.13
Overweight	79.92	1.44	84.74	1.79	93.64	1.53	92.24	1.60

covariates – liking and familiarity ratings (liking: $F_{(1,1986)} = 8.51$, $p = 0.004$; familiarity: $F_{(1,1986)} = 15.52$, $p < 0.001$).

The same statistical model – the mixed-model ANCOVA – was also applied to the dataset of EI. The results suggested significant main effects due to the Plate Size ($F_{(1,1986)} = 5.25$; $p = 0.048$), BMI Group ($F_{(1,1986)} = 42.22$, $p < 0.001$) and Dish ($F_{(9,1986)} = 9.84$, $p < 0.001$). Of particular interests, the results showed that the EI rating of the small plate (M = 89.11, SE = 0.284) was significantly lower than that of the large plate (M = 94.09; SE = 0.276), and the EI rating of the normal-weight group (M = 80.06, SE = 0.299) was significantly lower than that of the overweight group (M = 93.14, SE = 0.367). In addition, slight yet significant differences were observed across the ten dishes, as shown in Figure 2 (Panel B).

The results also showed that the Plate Size was significantly interacted with the BMI Group for influencing the EI ratings ($F_{(1,1986)} = 27.26$, $p < 0.001$). Averaged EI ratings from the separate BMI group for each of the plate sizes are presented in Table 2. Post-hoc test with Bonferroni corrections showed that the plate size only had a significant effect on EI ratings for the normal-weight group ($p < 0.05$), but not for the overweight group. No other significant interaction was observed in the result of this model.

In order to further disentangle interactions between the tested factors, a series of paired-sample t-tests were performed, separately for the normal-weight and overweight group, on ES and EI ratings. The results (Table 3) indicated similar differences between weight groups for the ES ratings – eight dishes being rated significantly differently when they were placed on different plates. Notably, results from Dish 0 and 7 did not present significant difference between the large and small plate. For the EI ratings, the normal-weight group reported significant differences between the large and small plates for six dishes, whereas the overweight group reported no difference. These results further consolidated the findings obtained from the mixed-design ANCOVA.

Table 3 Results from paired-sample t-tests, conducted separately for normal-weight and overweight group, on estimated satiation (ES) and intake (EI) for the ten food images. The results include the difference in the mean ES/EI ratings between the large and small plate (L-S), their associated standard errors (SE) and resulting p-values. Significant p-values (<0.05) are in bold

| | Estimated satiation (ES) | | | | | | Estimated intake (EI) | | | | | |
| | Normal weight | | | Overweight | | | Normal weight | | | Overweight | | |
Dish	L-S	SE	*p*-Value	L-S	SE	*p*-Value	L-S	SE	*p*-Value	L-S	SE	*p*-Value
0	2.686	2.763	0.572	2.884	2.382	0.321	2.208	1.620	0.179	2.302	1.151	0.052
1	−5.060	2.455	**0.045**	−4.805	1.874	**0.001**	1.941	1.812	0.289	3.881	2.267	0.087
2	−2.942	1.474	**0.050**	−3.970	1.932	**0.041**	3.510	1.730	**0.047**	−2.643	2.321	0.261
3	−9.706	2.141	**0.000**	−7.659	2.275	**0.002**	4.735	1.761	**0.010**	2.000	2.381	0.406
4	−7.596	1.494	**0.000**	−8.286	1.842	**0.000**	3.938	1.466	**0.010**	2.558	1.709	0.142
5	−5.353	1.349	**0.038**	−4.535	1.252	**0.003**	3.082	1.466	**0.036**	−1.326	1.428	0.359
6	−5.804	1.420	**0.000**	−5.488	1.823	**0.004**	0.940	1.239	0.452	1.419	1.356	0.301
7	1.577	1.830	0.393	4.146	2.133	0.059	−3.146	1.824	0.091	−0.310	1.630	0.850
8	−10.529	2.348	**0.000**	−15.429	3.302	**0.000**	4.178	1.879	**0.002**	3.025	1.848	0.110
9	−7.118	1.681	**0.000**	−6.537	2.080	**0.003**	3.327	1.606	**0.039**	−1.953	2.202	0.380

Note: For the t-test, data of the large plate were the first variable, and data of the small plate were the second variable. Thus, negative t-statistics indicates that larger plates are associated with lower estimates. Degree of freedom is 122 for the normal-weight group, and 77 for the overweight group.

Discussion

Findings from the present study pointed to a potential role of body weight in moderating the plate-size-effect. Despite the fact that both groups rated foods on the small plates to be more satiating, only the normal-weight group reported their EI ratings in accordance with this perceptual bias. On the contrary, individuals in the overweight group gave similar EI ratings for foods on both the large and small plates, which were significantly higher than the EI ratings from the normal-weight group. In line with some previous data (27,28), these results implied that the overweight group were more inclined to clean the plate, and therefore less susceptible to the plate-size-effect. This finding may be relevant to another recent study, in which the susceptibility to the plate-size-effect was found to be correlated with the individual's level of intuitive eating (24). Tentatively, a potential relationship may be present between an individual's body weight and level of intuitive eating, both of which in turn influence the plate-size-effect.

With regards to the relationship between the weight status and the plate-size-effect, findings from the present study presented contradictory evidence to previous studies. The available evidence in the literature suggested little effect of plate size on food or energy intake for either normal-weight or overweight group (17,25,26). Discrepancy between the previous and present studies may be attributed to differences in the methodologies. Previous studies typically used an *ad libitum* design in a buffet setting, which gave a more realistic account of the eating situation, but could also introduce bias to the participant's eating behaviours (26,29). Findings from the present study tentatively support the use of VAS on food images for capturing different responses to plate sizes.

In addition to BMI, the type of dish was shown to have a significant effect on the plate-size-effect. As the results indicated, the plate size did not affect the ES rating for Dish 0 and 7, differing from the observations from the other eight dishes. In addition, review of the main effect of ES suggested that Dish 0 and 7 received significantly lower ES rating than other dishes. This suggested that the overall ES rating of a dish might have provided a baseline for the plate-size-effect. In other words, a dish with a low ES rating is associated with a small likelihood of the presence of the plate-size-effect.

Relating to the effect of dishes, liking and familiarity, as covariates in the statistical model, were shown to be influential on the plate-size-effect by ES. However, these measures were comparable across the BMI groups. The role of liking or familiarity was never assessed previously in the context of plate-size-effect, but it was learnt from studies of 'portion estimation' that both liking and familiarity were correlated to estimated food portions, although directions of these correlations were not consistent across foods (30,31). Future studies are required to confirm whether liking or familiarity can directly moderate the plate-size-effect, but evidence from the present study eliminated the role of liking or familiarity in mediating the interaction between BMI and the plate-size-effect.

A possible limitation of this study was that the participants were not asked to report their state of hunger at the time of testing. Another factor that might have introduced potential bias was that participant's BMI was based on self-reported data, instead of empirical measures. Finally, the choice of the VAS method should be considered when interpreting the current findings. Future studies should further verify these findings using other common method, such as the method of adjustment (5).

Overall, the present study revealed that BMI could have a moderate effect on individual's susceptibility to the plate-size-effect. This finding was possibly explained by different tendencies between the normal-weight and overweight group to 'clean the plate'. This study also suggested some potential moderators for the plate-size-effect, such as the type of dish, and its associated appeal and familiarity. Altogether, these findings provided additional knowledge about the plate-size-effect and gave further suggestions on the effectiveness of using small plates for prevention of overeating.

Conflict of Interest Statement

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