

1 Introduction

Marketers seek to make product packaging as attractive as possible in order to convince consumers to buy their products (Velasco & Spence, 2019). Indeed, consumers perceive aesthetic packaging to be both exciting and appealing (Reimann et al. 2010). What is more, it also increases their willingness to pay for the product concerned (Bloch et al. 2003). To make food packaging attractive, the serving size pictured on the front of product packaging is often exaggerated, thus exceeding the recommended calories/grams for a portion that is stated on the nutrition label (Brand and Wansink 2016; Tal et al. 2017). For example, visual portions on the front of cereal boxes exceed the calorie recommendation on the nutritional label by an average of 64.7% (Tal et al. 2017).

One problem is that such high-calorie food images can surreptitiously influence consumption norms and hence “*nudge*” actual serving sizes in an undesirable direction (Guthrie et al. 2015; Thaler and Sunstein 2008). Indeed, it has been shown that portion size is used by consumers to evaluate how much it is reasonable to eat (Versluis and Papies 2016). For this reason, consumers not only serve themselves more, but also consume more, from larger packages than from smaller ones. This is called the “*portion size effect*” (Geier et al. 2006; Rolls et al. 2002; Petit et al. 2017; Wansink et al. 2005¹). The food portion pictured on product packaging can also affect food serving (Brand and Wansink 2016; Tal et al. 2017). For instance, exaggerated serving sizes depicted on the packaging lead participants to serve themselves 17.8% more cereals than those who viewed visuals illustrating the recommended serving size (Tal et al. 2017).

This raises the question of how to make food pictures more appetizing and so enhance purchase intent without necessarily increasing the size of the ensuing self-serving. Previous

¹ Note that Wansink et al. (2005), as well as other work by Brian Wansink, has recently come under scrutiny, and it appears that it contains some errors (e.g. <https://medium.com/@jamesheathers/sprite-case-study-5-sunset-for-souper-man-ee898b6af9f5>). However, other researchers in the field have also studied and put forward the portion size effect (e.g. Geier et al. 2006; Rolls et al. 2002; Petit et al. 2017).

research highlighted that changing the size of the plate can bias serving size perceptions (van Ittersum and Wansink 2012). This perceptual bias, also known as the “*Delboeuf illusion*”, has been shown to affect food serving. However, to the best of our knowledge, no one has yet investigated whether changing the size of the plate pictured on the front of packaging can similarly affect the serving size. Showing food items on a plate on the front of the packaging is quite common for some products (e.g., frozen pizza $\approx$ 41.5%, cereals $\approx$ 87.5%, see openfoodfacts.org/)². The plate is generally small-rimmed (in 98.5% of cases), thus people perceive the portion larger than it actually is. However, it might be unrealistic to increase the size of the plate on the front of the packaging in order to reduce perceptions of portion size. Indeed, increasing the size of the container might give the impression of a portion that looks too small, possibly reducing the attractiveness of the product. By contrast, reducing the size of the container without changing the amount of food, might improve the attractiveness of the package without necessarily leading to any increase in self-serving.

2 Conceptual background and hypotheses

2.1 The Delboeuf illusion

This visual illusion, first documented by Franz Joseph Delboeuf in 1865, occurs when one of two identical circles is surrounded by a much larger circle while the other one is surrounded by a circle that is only slightly larger. In the latter case, the central circle appears larger than the equal-sized circle that happens to be surrounded by a much larger one (see Appendix 1a). Importantly, when the circles are replaced by foods on plates/bowls, the same portion-size illusion occurs, but without affecting the actual quantity of food shown on the plate (see Appendix 1b). In this context of food consumption, the Delboeuf illusion biases the

² openfoodfacts.org/ is a free and open database of food products from around the world, generally providing a picture of the food packaging. We have listed 128 packets of corn flakes and 224 packets of cheese pizza sold in 26 countries. All of the pizza plates were small and we only found three bowls of cereals that were not small rimmed.

ability of consumers to determine the size of the food portion, and thus the appropriate serving size (McClain et al. 2014; van Ittersum and Wansink 2012). Marketers can potentially use this strategy to make their products appear "larger" on the images presented on the front of product packaging, as can be observed on packages of cereals (Kellogg's, Quaker), frozen pizza (Ristorante, Di Giorno), other frozen dishes (macaroni and cheese, meat loaf with corn, turkey meal with peas: Banquet), or cake mix (Betty Crocker).

2.2 The Delboeuf illusion, mental simulations, and food craving

The presence of appetizing food pictures on product packaging undoubtedly captures the attention of consumers in-store (Sawada et al. 2017). Viewing the latter leads to the automatic generation of mental simulations of food consumption (Papies 2013). Such mental simulations are thought to be based on the implicit reenactments of previous eating experiences, stimulated by exposure to verbal or visual representations of food (Barsalou, 2008). Supporting this idea, neuroimaging research has demonstrated that viewing food pictures activates some of the same brain areas whose activity is known to increase during the actual processing of gustatory stimuli (Basso et al. 2018; Van der Laan et al. 2011). Thus, appetizing food cues reactivate reward representations stored in memory, which can then motivate consumers to purchase the products (Elder and Krishna 2012, Petit et al., 2016b; Petit et al. 2017; Spence et al. 2016; Xie et al. 2016).

However, not all food images stimulate positive mental representations. Supersized pictures of high-calorie foods seem to stimulate consumer mental imagery more easily than undersized pictures of low-calorie foods (Toepel et al. 2015). High-caloric pictures lead to increased activity in gustatory and reward-related areas as compared to low-caloric pictures (Basso et al. 2018; Van der Laan et al. 2011). This responsiveness to high-calorie foods can be explained by the fact that detecting energy-rich foods was once essential to ensuring

adequate nutrition (and ultimately survival). Similarly, Toepel et al. (2015) found an incremental increase of activity in gustatory and reward-related brain areas as portion size increases. Thus, by presenting food items in supersized portions on the front of the packaging, marketers might suggest to consumers that their products will be refueling, so increasing their attractiveness. Since the Delboeuf illusion can be used to give the impression that there is more food on a plate or in a bowl by using a small container (McClain et al. 2014; van Ittersum and Wansink 2012), one might expect that large (vs. small) portion illusions will stimulate food craving. Thus, we hypothesize that:

H1: People will express greater purchase intentions when the food pictured on the front of the packaging is displayed on a smaller (larger portion illusion) rather than on a larger plate (smaller portion illusion).

H2: People will evaluate a food product as more appetizing when the food pictured on the front of the packaging is displayed on a smaller rather than on a larger plate.

2.3 The Delboeuf illusion, mental simulations, and serving size

According to previous studies, exaggerated portion sizes on food packaging cause consumers to serve themselves more than from food packaging depicting a single-size portion matching the suggested serving size (Brand and Wansink 2016; Tal et al. 2017). However, the Delboeuf illusion only artificially increases the portion size (the quantity of food itself does not change). Thus, the Delboeuf illusion might have an impact on perception (i.e., how appealing the food looks), but not on action (i.e., how much food is served; Aglioti et al. 1995; Franz et al. 2000). It may be necessary for consumers to pay attention to the picture on the food packaging and to simulate eating experiences in order for the Delboeuf illusion to influence the amount of food served (Elder and Krishna, 2012; Madzharov and Block 2010;

Petit et al. 2017). Madzharov and Block highlighted that the effects of the number of product units displayed on a package on actual consumption was moderated by the level of visual processing (i.e., how much people rely on graphics, diagrams, and illustrations in order to process visual information). Similarly, Elder and Krishna have shown that embodied mental simulations mediate the impact of the visual product depiction on purchase intentions. Thus, we hypothesize that:

H3: The number of mental simulations of the eating experience will mediate the impact of the Delboeuf illusion on the amount of food served.

However, the fact that consumers pay attention to the picture on the packaging does not mean that they will necessarily increase their self-serving in the presence of a larger portion illusion (Petit et al. 2017; Toepel et al. 2015). If the sight of large food portions leads to an increase of neural activity in gustatory and reward-related brain areas, evaluating the size of a food portion may elicit another pattern of brain activity (Toepel et al. 2015). The authors found maximal activity in response to portions judged as ‘ideal’ compared to ‘non-ideal’ (i.e., ‘too small’ and ‘too big’) in brain areas that are associated primarily with conscious awareness, cognitive control, and adaptive behavior. These results therefore suggest that if consumers find a larger (vs. smaller) food portion more appetizing, they might nevertheless still control their self-serving behavior.

By simulating the experience of eating a portion of food, consumers might become more conscious of the portion size, and consequently the appropriate quantity of food to eat. This positive effect of mental simulations would be consistent with an embodied vision of self-regulation, according to which “*being more conscious of one’s bodily states (and their simulation) in response to appetitive stimuli may be beneficial to pursuing healthy goals*” (see

Petit et al. 2016a, p. 612). In this way, Petit et al. (2017) found that those individuals who simulate more (vs. less) vivid experiences of eating, when viewing a picture of a portion of food, selected a smaller (vs. not significantly different) percentage of food from the very large portion than from the smaller portions. Thus, those individuals who simulate more vivid experiences of eating were less sensitive to the portion size effect. In that sense, presenting appealing images that give rise to a larger portion illusion would likely lead to embodied self-regulation in those consumers with more vivid eating simulations, thus potentially leading to smaller amounts of food served. Therefore, it can be hypothesized that:

H4: People will select less food to eat when the food pictured on the front of the packaging is displayed on a smaller rather than on a larger plate.

Two studies were conducted to test Hypotheses 1-4. Study1 was conducted online, to evaluate the effects of the portion size illusion on consumer behavior when product evaluation is disconnected from consumption. Study 1 corresponded to an online shopping situation, and was used to test Hypotheses 1, 3, and 4. Study 2 was performed in a laboratory setting, in which product evaluation was followed by real food serving. Study 2 corresponds to a food consumption situation, and was used to test Hypotheses 2-4.

3 Study 1: Online evaluation

3.1 Participants

102 participants (46 females, mean age = 30.65 years, $SD = 9.38$) were recruited using Prolific Academic (<http://prolificacademic.co.uk/>) to take part in the online study.

3.2 Design and procedure

Two versions of a frozen pizza box with a plate printed on the front of the packaging were created. The Delboeuf illusion was used to modify the perceived size of the pizza on the plate. The same pizza was printed on the front of both versions, but shown against either a larger or smaller plate (see Appendix 2). The participants were randomly assigned to either condition.

After viewing the manipulated graphics on the product packaging, participants indicated the percentage of the pizza that they would like to eat in one go. To determine whether the food portion size illusion was perceived by participants, they rated how big the pizza looked to them. The participants were also asked about their purchase intentions with 7-point Likert scales. A three-item scale was used to measure the simulation of eating experiences (Elder and Krishna 2012). The participants rated the extent to which mental images of eating a slice of pizza came to mind, the number of images of eating a slice of pizza that came to mind, and the extent to which they could imagine eating a slice of pizza. These measures were combined to generate a scale for the “number” of eating simulations (Cronbach's $\alpha = .86$), indicating whether the participants reported “more” or “less” mental simulations of eating.

3.3 Results

Mann-Whitney tests were conducted with portion size illusion as the independent variable on the dependent variables, as the samples were not normally distributed. An independent samples t-test was conducted on the percentage of food selected (see Table 1 for descriptive statistics and statistical tests). The hypothesized moderating role of mental simulations was tested using the Process macro (5000 bootstrap samples).

A Mann-Whitney test indicated that the pizza was rated as looking significantly larger (by 20.18%) when shown on the smaller plate ($M_{\text{Larger portion illusion}} = 3.94$, $SD = 1.43$) than on

the larger plate ($M_{\text{Smaller portion illusion}} = 3.32$, $SD = 1.54$, $U = 988$, $p = .03$, $r = -.21$). Confirming Hypothesis 1, participants expressed higher purchase intentions when the pizza was displayed on the smaller plate ($M_{\text{Larger portion illusion}} = 4.6$, $SD = 1.81$) than on the larger plate ($M_{\text{Smaller portion illusion}} = 3.80$, $SD = .1.82$, $U = 985$, $p = .03$, $r = -.23$; see Figure 1a). Confirming Hypothesis 4, the participants in Experiment 1 selected a smaller percentage of the pizza (-19.09 %) on the smaller ($M_{\text{Larger portion illusion}} = 33.69\%$, $SD = 16.34$) than in the larger plate condition ($M_{\text{Smaller portion illusion}} = 41.64\%$, $SD = 19.46$, $t(100) = 2.24$, $p = .03$; Cohen's $d = .44$, see Figure 1b). Controlling for the portion size illusion, the self-reported number of mental simulations did not significantly affect the percentage of pizza selected ($p = .11$). Thus, Hypothesis 3 was not confirmed.

4 Study 2: Laboratory evaluation

4.1 Participants

76 undergraduate students (22 females, mean age = 21 years, $SD = 3.04$) took part for extra credit in the study that ran as a two-condition (portion illusion: larger vs. smaller) between-participants experimental design.

4.2 Design and procedure

Two versions of a package of cereals with a bowl printed on the front of the packaging were created. The same quantity of cereals was shown on the front of both versions of the packaging, but served in either a larger- or smaller-rimmed bowl (see Appendix 3). The participants were instructed not to eat in the 4 hours prior to the experiment and were randomly assigned to either condition.

After viewing the manipulated graphics on the product packaging, the participants had to serve themselves the amount of food that they would like to eat in a medium-rimmed bowl.

The serving weight (in grams) was then recorded. To determine whether the participants perceived the food portion size illusion, they were asked to estimate the caloric content of the bowl of cereals shown on the packaging. The participants were also asked about how appealing the food looked, using 7-point scales. To measure the simulation of eating experiences, Elder and Krishna's (2012) three-item scale was also used in this second study (Cronbach's $\alpha = .90$).

4.3 Results

Similar to Study 1, Mann-Whitney tests were conducted with portion size illusion as the independent variable on the dependent variables, as the distributions were not normally distributed. An independent samples t-test was conducted for the weight of food serving (see Table 2 for descriptive statistics and statistical tests). The hypothesized moderating role of mental simulations was tested using the Process macro (5000 bootstrap samples).

The caloric content of the smaller-rimmed bowl ($M_{\text{Larger portion illusion}} = 179.87$ calories, $SD = 82.15$) was rated as significantly higher (26.86 %) than that of the larger-rimmed bowl ($M_{\text{Smaller portion illusion}} = 141.79$ calories, $SD = 73.55$, $U = 511.50$, $p = .03$, $r = -.25$).

Confirming Hypothesis 2, participants evaluated the cereals as looking more appetizing when shown in the smaller-rimmed bowl ($M_{\text{Larger portion illusion}} = 3.45$, $SD = 1.33$) than in the larger-rimmed bowl ($M_{\text{Smaller portion illusion}} = 2.76$, $SD = 1.48$, $U = 511.50$, $p = .03$, $r = -.26$; see Figure 2a for the means). Confirming Hypothesis 4, participants poured less cereals (-19.72%) from the packaging showing the smaller-rimmed bowl ($M_{\text{Larger portion illusion}} = 41.26$ g, $SD = 14.91$) than from the packaging showing the larger-rimmed bowl ($M_{\text{Smaller portion illusion}} = 51.39$ g, $SD = 24.80$, $t(74) = 2.16$, $p = .03$, Cohen's $d = .50$).

In support of Hypotheses 3, the vividness of mental simulations moderated the effect of the portion size illusion on the food serving ($\beta = 11.44$, $t(72) = 2.61$, $p = .01$). Examination

of the interaction plot revealed that those participants with medium and high scores of mental simulations poured less cereals (-23.16 %, -36.23%, respectively) after seeing the smaller-rimmed bowl ($M_{\text{Medium mental simulations}} = 41.12$ g, $M_{\text{High mental simulations}} = 41.96$) than after seeing the larger-rimmed bowl ($M_{\text{Medium mental simulations}} = 53.51$ g, $CI = 3.78, 21.01$, $M_{\text{High mental simulations}} = 65.80$, $CI = 11.70, 35.98$). Those participants with low mental simulation scores did not change their serving behavior as a function of the portion size illusion ($M_{\text{Larger portion illusion}} = 40.27$ g, $M_{\text{Smaller portion illusion}} = 41.23$, $CI = -11.46, 13.36$; see Figure 2b).

5 General Discussion

5.1 Summary

This article makes several contributions to the literature on food portion size and provides managerial insight concerning the fact that larger portion illusions pictured on food packaging offer a means to make the product more attractive while, at the same time, reducing self-serving. The two studies reported here demonstrate that similar to large portions presented on the front of food packaging, giving the illusion of a large portion can make food more appealing to consumers and increase their purchase intentions. Thus, seeing a picture of food served in a smaller container (large portion illusion) as compared to an image of food served in a larger container (small portion illusion) increased purchase intentions during online evaluation (Study 1), and the desire to eat during real serving (Study 2).

In both studies, the participants selected less food to eat when the smaller (vs. larger) portion illusion was displayed. In Study 2, the effect of the portion size illusion on the amount of food served was moderated by the vividness of mental simulations. Those participants with lower eating simulation scores did not change their serving behavior as a function of the portion size illusion. Interestingly, the serving was not significantly different between the three groups of participants (i.e., those with low, medium, and high mental simulation scores)

in the larger portion illusion condition, but increased for those participants with medium and high mental simulations scores in the smaller portion illusion condition. Thus, contrary to the exaggerated portion sizes depicted on many food packages, the larger portion illusion might make the food packages more appealing without necessarily increasing self-serving (Tal et al. 2017). By contrast, displaying a portion (illusion) on food on the packaging that is too small might increase self-serving.

An explanation for the fact that the larger portion illusion did not affect the self-serving of participants who exhibited low mental simulation scores might be that they did not pay attention to the packaging design and/or were not very motivated to eat the food itself (Elder and Krishna, 2012; Madzharov and Block 2010; Petit et al. 2017). Interestingly, the package that gave rise to the larger portion illusion was rated as more appetizing and perceived as being more calorific. According to Brunstrom and Shakeshaft (2009), a food is regarded as rewarding, and a smaller portion is chosen, when it is liked and has high expected satiety. The larger food portion illusion could make the food more rewarding, especially for those who imagine the eating experience more vividly, thus leading them to serve themselves a smaller quantity of food. The mediating role of the mental simulation of eating experience identified here supports the idea that considering sensory information and consequent simulations helps consumers to select the appropriate portion size to achieve their homeostatic balance (i.e., embodied self-regulation, Petit et al. 2016a, 2017).

5.2 Managerial implications

By using the Delboeuf illusion on their packaging, food marketers/manufacturers might be able to promote their products without necessarily encouraging consumers to over-consume potentially unhealthy portions. Displaying a large portion of food on the front of food packaging may suggest that consumers will be able to satisfy their hunger by purchasing

the product (Brunstrom and Shakeshaft 2009). However, it is not necessary to present a large amount of food in order to make the product appetizing. By changing the size of the plate, food marketers can increase consumers' buying intentions without necessarily increasing subsequent food servings. Aside from its interest in fighting obesity, reducing food serving by playing with the Delboeuf illusion on food packaging may have positive indirect effects for food marketers. When consumers expect satiety from a product that they like, they tend to select a smaller portion and are willing to pay more for it (Brunstrom and Shakeshaft 2009; Cornil and Chandon 2016). Thus, when exposed to large portion illusions on the front of food packaging, consumers might spend more money to get a smaller package size. Therefore, food marketers might be able to charge more for less food.

Interestingly, our results suggest that it may not be relevant to reduce portion sizes on the front of food packaging, as suggested by previous works (Tal et al. 2017; van Ittersum and Wansink 2012). The danger is that showing too small a portion (on the front of food packaging) might “*nudge*” consumers to overserve (Guthrie et al. 2015; Thaler and Sunstein 2008). Indeed, consumers might not expect to be sated by consuming the portion, and might therefore serve themselves more food in order “to compensate” for this ‘too small’ portion, with a negative effect on purchase intentions (Brunstrom and Shakeshaft 2009; Petit et al. 2016a, 2017; Toepel et al. 2015).

5.3 Limitations and further research

Study 1 was conducted online while Study 2 was conducted in a laboratory setting. As such, participants may have been more focused on the package than they would have been if they were standing in front of a supermarket shelf with many other food products on display, or while sitting at the family breakfast table. The most ecological way in which to study portion size illusion effects on self-serving behavior would be to assess it in the consumer’s

own home (or else, wherever they normally happen to consume cereals). To study the effects of portion size illusion on real purchase behavior, supermarket till receipts could also potentially be analyzed (e.g., Kühn et al. 2016). It would be interesting to conduct long-term follow-up studies, in order to test whether the effects of the portion size illusion depicted on food packaging dissipate over time.

Another limitation of the present study is that we did not evaluate the perceived healthfulness of the food portion. Labbe et al. (2017) demonstrated that the selection of a portion of food is determined both by its perceived healthfulness and by its expected tastiness. Further studies should therefore include these variables and test the effects of the food portion illusion on the serving of different food categories (broccoli, apple, and candy bar). It may also be worthwhile to conduct a similar study, adding a message on the packaging (such as “imagine eating this bowl of cereals”) to accentuate, via instructed mental simulation, the effect of the food portion illusion (Xie et al. 2016).

Peng et al. (2017) recently reported that manipulating the size of the plate (in order to create larger vs. smaller portion illusions) has no effect on the expected fullness or the estimated intake of Chinese and Koreans consumers (as compared to significant effects in those from Canada and New Zealand). Further studies should investigate how cultural influences affect food serving ‘illusions’ as a function of the portion pictured on the front of food packaging. We might also need long-term studies to see the effect of repeated exposure to visual stimuli on packaging over time (cf. Akyol et al. 2018).

To finish, the present research can be used to drive recommendations as to how to design packaging to promote products that can be served directly in a bowl or on a plate (cereals, ice-cream). The ways to make the food consumed directly from the package (chips, candies), cooked before eating (paste, rice), or from individual portions (French fries, soft drinks), more appealing without encouraging consumers to overeat, undoubtedly need to be

researched further. Nevertheless, the present research provides some encouraging results from which future studies may build.

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Table 1 : Study 1

Descriptive statistics

Portion size illusion	Portion size perception	Purchase intent	Serving (percentage of the pizza)
Larger	3.94 (1.43) ^a	4.60 (1.81)	33.69 (16.34)
Smaller	3.32 (1.58)	3.80 (1.82)	41.64 (19.46)
Total	3.64 (1.53)	4.21 (1.85)	37.59 (18.29)

^a Numbers in parentheses represent standard errors of the means.

Statistical tests

	Portion size perception	Purchase intent		Serving
Mann-Whitney U	988	985	t-value	2.24
p	.033	.033	p	.028

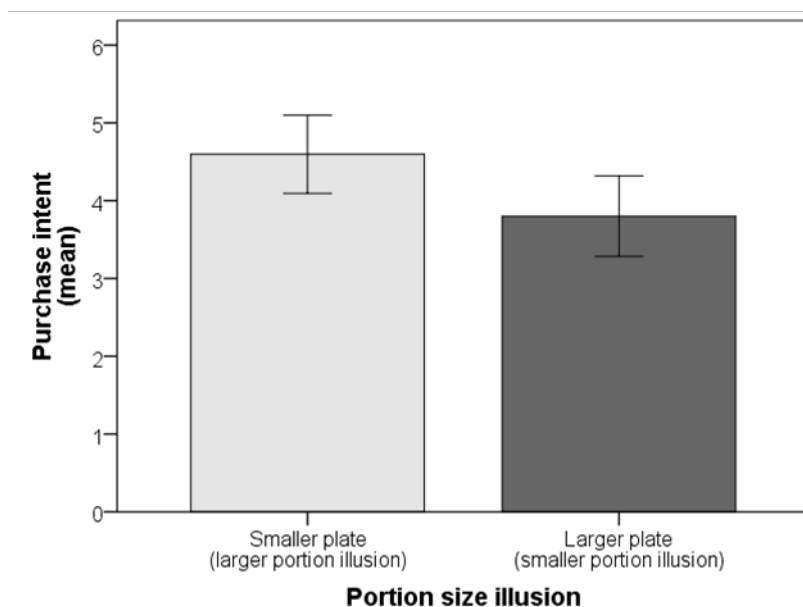
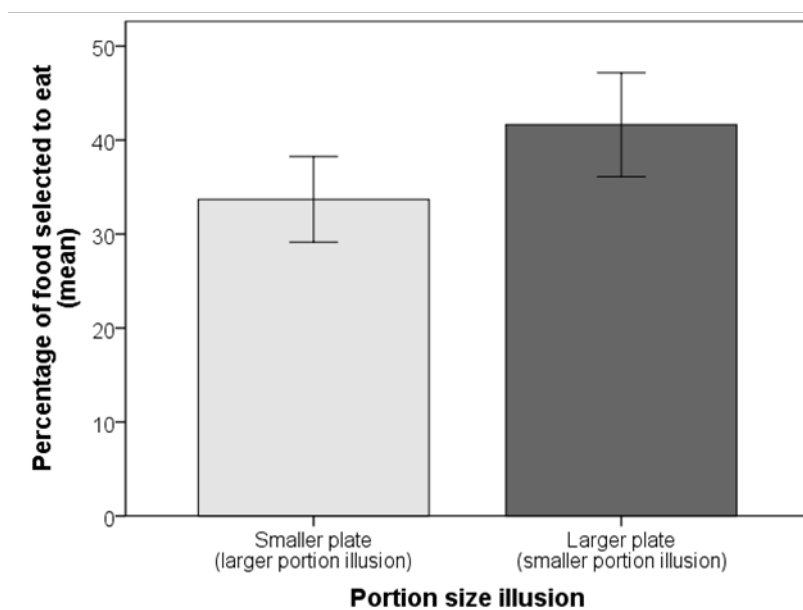
a. Purchase intent**b. Food serving**

Fig. 1 Study 1. Product evaluations: **a.** purchase intent, **b.** percentage of food selected to eat, in the smaller (larger portion illusion) and larger plate (smaller portion illusion) conditions. Error bars represent the 95% confidence intervals.

Table 2. Study 2

Descriptive statistics

Portion size illusion	Caloric content	Appetizing	Serving (grams)
Larger	160.42 (69.23) ^a	2.90 (1.24)	40.42 (15.84)
Smaller	133.95 (72.74)	2.11 (1.15)	42.79 (21.10)
Total	147.18 (71.32)	2.50 (1.25)	41.61 (18.44)

^a Numbers in parentheses represent standard errors of the means.

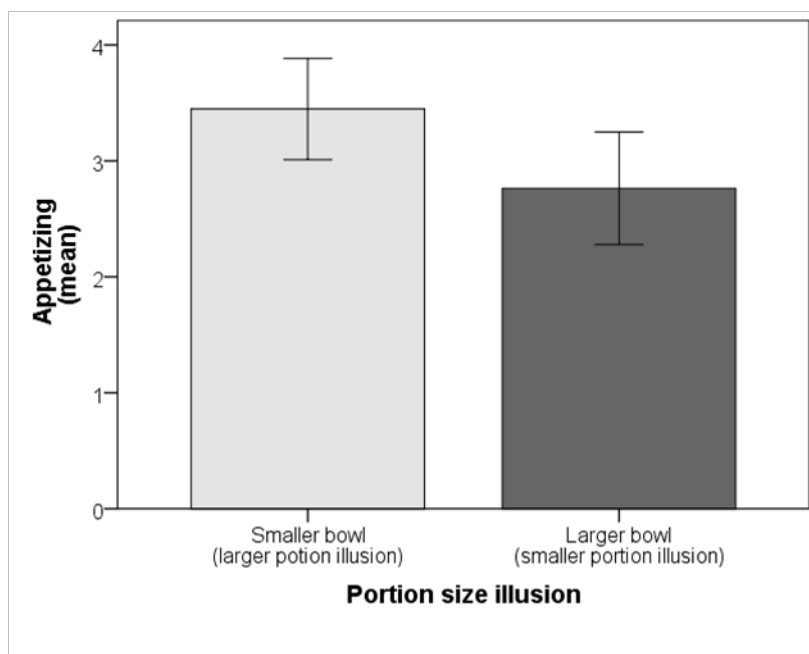
Statistical tests

	Caloric content	Appetizing	Serving		
Mann-Whitney U	511.50	511.50	Regression coefficients from moderation	β	95% CI
			Mental imagery	6.57**	[2.20; 10.94]
p	.029	.025	Portion size illusion	12.40**	[3.78; 21.01]
			Interaction	11.44*	[2.70; 20.19]

***: $p < .01$; *: $p < .05$

The CIs are the bias-corrected bootstrap 95% confidence intervals.

a. Appetizing



b. Food serving

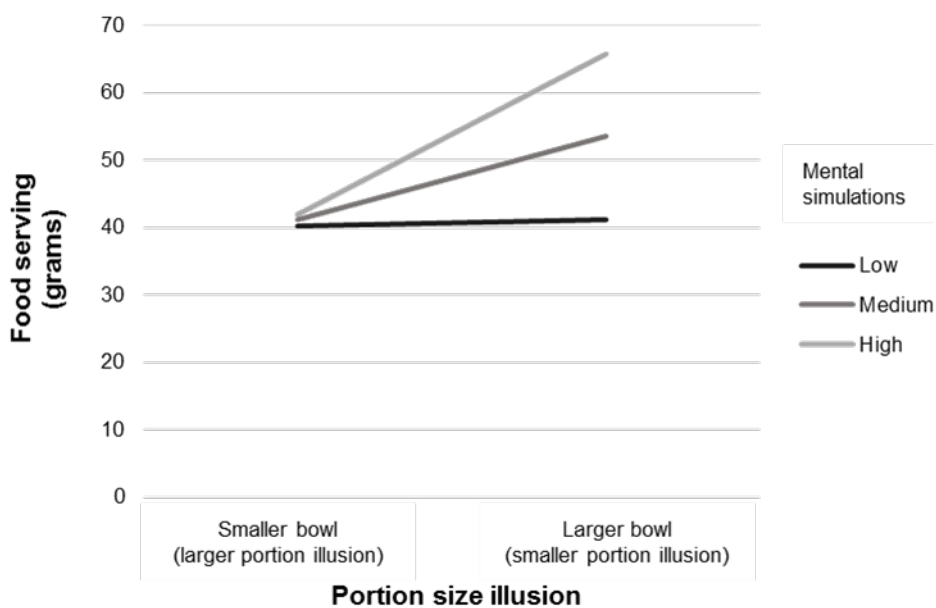
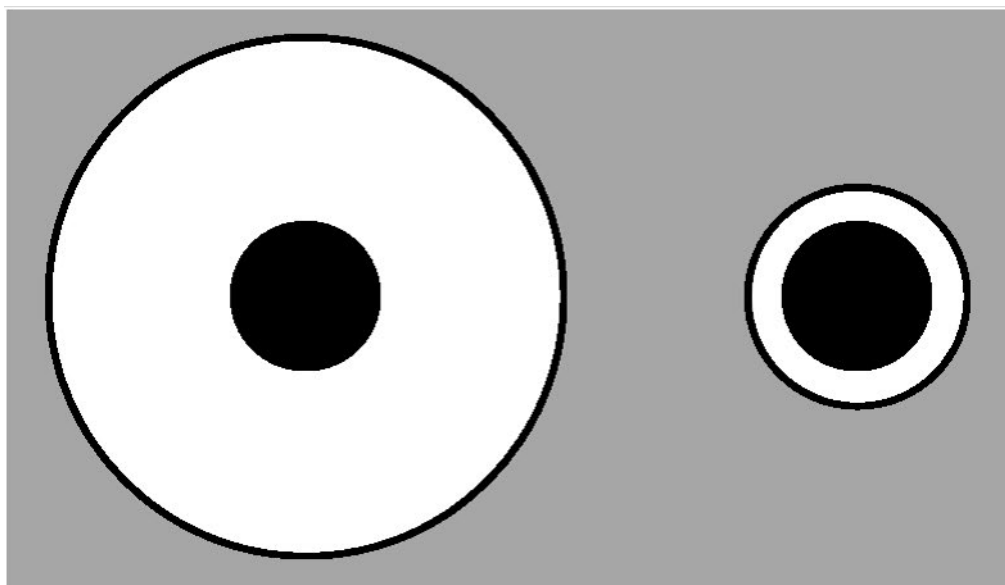


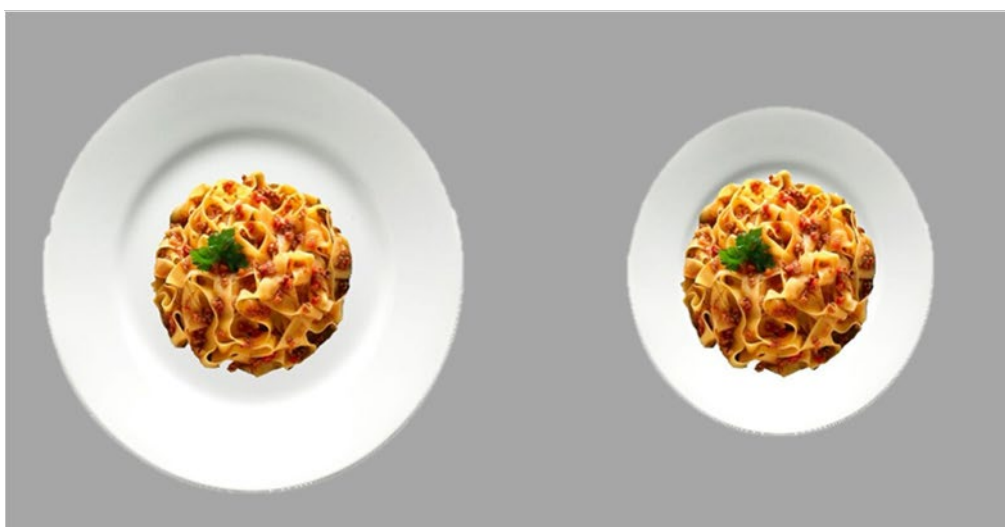
Fig. 2 Study 2. Product evaluations: **a.** appetizing, Error bars represent the 95% confidence intervals. **b.** food selected to eat (in grams), in the smaller-rimmed (larger portion illusion) and larger-rimmed bowl (smaller portion illusion) conditions, for participants with low, medium, and high mental simulation scores.

Appendix 1: The Delboeuf illusion

a. Standard Delboeuf illusion



b. Food on large vs. small plate



Appendix 2: Study 1 stimuli

Delboeuf illusion shown with pizza on a plate printed on the front of the packaging. The visual presentation giving rise to the larger portion illusion (left) was rated as looking 17% larger than the visual presentation giving rise to the smaller portion illusion (right).



Appendix 3: Study 2 stimuli

Delboeuf illusion shown with cereal bowls printed on the front of the product packaging. The larger portion illusion (left) was rated as looking 27% more calorific than the smaller-looking portion illusion (right).

