Plate Size and Color Suggestibility: The Delboeuf Illusion's Bias on Serving and Eating Behavior

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Despite the challenged contention that consumers serve more onto larger dinnerware, it remains unclear what would cause this and who might be most at risk. The results of five studies suggest that the neglected Delboeuf illusion may explain how the size of dinnerware creates two opposing biases that lead people to overserve on larger plates and bowls and underserve on smaller ones. A countercyclical sinus-shaped relationship is shown to exist between these serving biases and the relative gap between the edge of the food and the edge of the dinnerware. Although these serving biases are difficult to eliminate with attention and education, changing the color of one's dinnerware or tablecloth may help attenuate them. By showing that the Delboeuf illusion offers a mechanistic explanation for how dinnerware size can bias serving and intake, we open new theoretical opportunities for linking illusions to eating behavior and suggest how simple changes in design can improve consumer welfare.

There is a growing belief that the size of dinnerware influences how much people serve and consume during a single serving occasion. Indeed, the three largest health-related websites—WebMD.com (86 million visitors per month), NIH.gov (31 million), and Medicinenet.com (14 million)—each recommend that consumers replace larger dinnerware with smaller dinnerware to reduce consumption. A seemingly obvious initial explanation is that smaller dinnerware simply has less food capacity (Rozin et al. 2003). Yet even when plates and bowls are exaggeratedly large and capacity is not a constraint, the average consumer—including dieticians and nutrition experts—consistently serves more onto relatively larger dinnerware than onto relatively smaller dinnerware (Wansink 2006). Knowing why this occurs will enable useful, low-involvement interventions to be developed for health-care professionals, policy makers, dishware designers, dieters, and responsible parents.

From a consumer welfare perspective, the effect of dinnerware size on serving behavior is significant, since the average size of a sample of dinner plates increased almost 23%, from 9.6 inches to 11.8 inches, since 1900 (see fig. 1). Should the size of a plate or bowl encourage a person to eat only 50 more calories a day, the resulting mathematical increase in weight would be approximately 5 pounds each year. Whereas we know that the shape of a glass (or cylinder) can influence visual perceptions of volume (Chandon and Ordabayeva 2009; Raghubir and Krishna 1999), serving behavior, and consumption (Wansink and Van Ittersum 2003, 2005), it is not known when and why this might happen with dinnerware, and what could most easily be done to prevent it.

In 1865, Delboeuf documented a puzzling perceived difference in the size of two identical circles when one of the circles was surrounded by a much larger circle and the other one was surrounded by only a slightly larger circle. We

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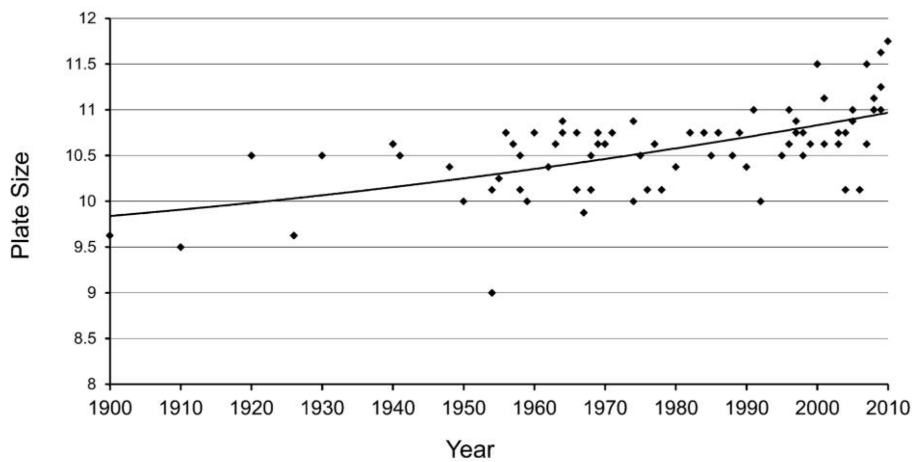
FIGURE 1

THE SIZE OF AMERICAN-MANUFACTURED PLATES APPEARS TO INCREASE FROM 1900 TO 2010



NOTE.—To investigate this general trend, we plotted the dates and the sizes of all the different American dinner plates being offered for sale on eBay.com on March 31, 2010. Among this sample frame of distinct American plates ($N = 75$), the basic correlation between date and dinner plate size was $r = 0.59$ ($p < .01$).

propose that the well-established perceptual biases described by this Delboeuf illusion may explain how and why the size of dinnerware causes serving biases that occur meal by meal. Such biases imply an important interplay between perceptions and compensating serving behavior. In turn, this suggests that not all consumers may be similarly influenced by environmental cues, but it might be magnified by situational variables. There are four contributions of this research.

1. It introduces the Delboeuf illusion as a neglected but possible explanation for the link between the size of dinnerware and serving biases.
2. It extends the Delboeuf illusion from the perceptual to the behavioral domain, thereby helping refute the notion that there are separate visual pathways for perception and action that prevent visual illusions from having behavioral consequences (Franz et al. 2000).
3. It theorizes and demonstrates that there is a greater tendency for consumers to be mindlessly influenced by these environmental cues if they are distracted, unaware, or uneducated.
4. It demonstrates how the color contrast between the food, the dinnerware, and the tablecloth influences the Delboeuf illusion.

This research is organized as follows. First, the Delboeuf illusion is introduced as a potential explanation for the link between the size of dinnerware and serving behavior and consumption. Second, four lab studies examine the opposing biases resulting in underserving and overserving. Following this, a field experiment investigates the robustness of these biases in a luncheon context. Key findings for health professionals, public policy makers, and responsible parents are outlined along with a range of suggestions that may help improve consumer welfare.

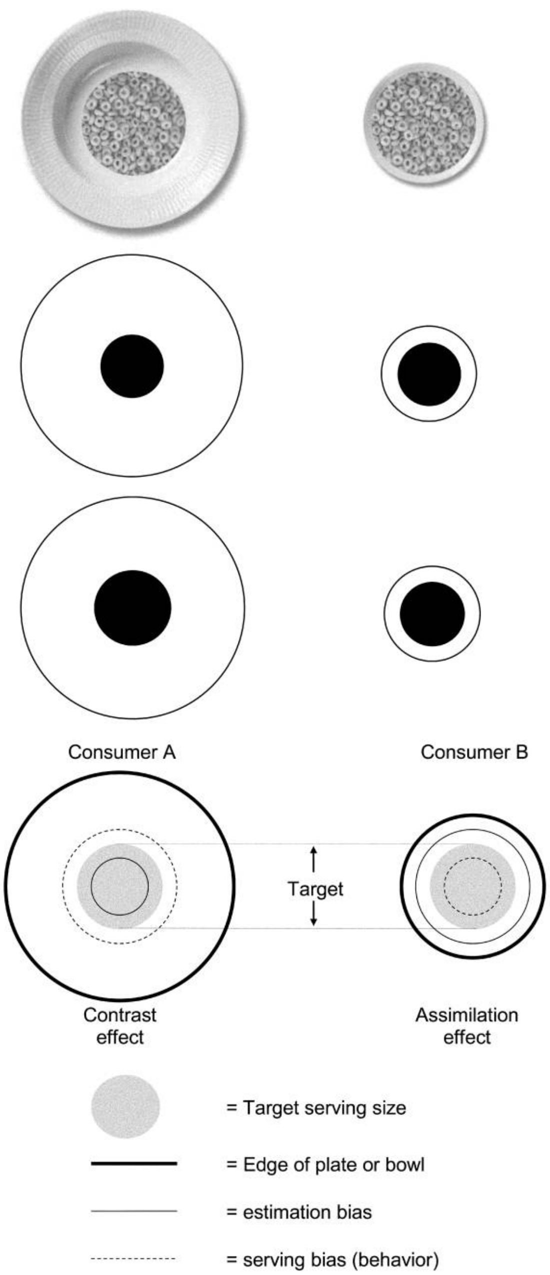
HOW PERCEPTUAL ILLUSIONS BIAS SERVING SIZE ESTIMATES

Despite contentions that dinnerware size positively influences serving and consumption behavior, it remains unclear why this might happen. This lack of understanding hinders a deeper investigation that could suggest key moderating conditions and simple, straightforward solutions to the potential problem. For instance, it remains unclear why Wansink, Van Ittersum, and Painter (2006) found that even nutritional experts (nutrition professors and graduate students) served and ate more at an ice cream social when given larger dinnerware, while Rolls et al. (2007) found people eating in isolated tasting booths did not.

When investigating the visual perception literature in this area, it is striking to note the resemblance between a plate filled with food and the two concentric circles that constitute the Delboeuf illusion (compare the top two rows of fig. 2). As indicated earlier, Delboeuf (1865) demonstrated an interesting perceived difference in size between two identical circles when one was surrounded by a much larger circle and the other one was surrounded by only a slightly larger circle. His finding may help resolve the puzzle of dinnerware size and serving biases.

FIGURE 2

DINNERWARE SIZE AND THE DELBOEUF ILLUSION



NOTE.—Food on large vs. small plate (first row); standard Delboeuf illusion (second row); nonstandard Delboeuf illusion (third row); estimation and serving biases (fourth row).

The Delboeuf illusion is illustrated in the second row of figure 2. Here the same-sized central circle (the test circle) appears smaller when surrounded by a much larger concentric circle (the inducing circle) than when instead surrounded by only a slightly larger concentric circle. A nonstandard version of this illusion is presented in the third row of figure 2, where the test circle on the right appears to have the same size as the test circle on the left—even though the left test circle actually is 20% larger. The Delboeuf illusion is visually robust with two-dimensional objects—the illusion is shown to exist for perfectly concentric circles but also for eccentric circles and, for instance, noncircular shapes such as squares, triangles, and rectangles (Weintraub and Cooper 1972; Weintraub and Schneck 1986).

It is well established that the Delboeuf illusion is caused by contrast and assimilation (Coren and Girgus 1978; Nicolas 1995; Oyama 1960; Ward and Lockhead 1970, 1971). More specifically, the *pool and store theory* explains this illusion based on the relative size of the gap between the test and the inducing circle (Goto et al. 2007; Jaeger and Lorden 1980; Nicolas 1995; Roberts, Harris, and Yates 2005). When the gap between both circles is relatively small and both circles are perceived as a whole (Morinaga 1935), individuals holistically pool and assimilate them in the short-term sensory store, leading the test circle (see fig. 2, second row) to be perceived as larger than it actually is (Girgus and Coren 1982). When the gap between both circles is relatively large and both circles are perceived as two separate percepts, individuals emphasize the differences between them and *contrast* both circles during the encoding process (Weintraub, Wilson, and Greene 1969), leading the test circle (see fig. 2, third row) to be perceived as smaller than it actually is (Pollack 1964). Although some variation exists based on the absolute size of the stimuli (Nicolas 1995), people are believed to be most susceptible to assimilation when the ratio between the diameters of the test and inducing circle is close to 0.67 (Piaget et al. 1942), and they are believed to be most susceptible to contrast when this diameter ratio is closer to 0.33 (Gentaz and Hatwell 2004; Ogasawara 1952).

The main objective here is to determine whether the well-established perceptual biases associated with the Delboeuf illusion have a corresponding effect on serving behavior. Our main contention is that the Delboeuf illusion biases consumers' ability to accurately determine how much food they need to serve to reach the target serving size they would otherwise typically serve and consume. Consider two consumers (A and B) who independently intend to serve themselves identical target serving sizes of cereal (see fig. 2, fourth row). Consumer A serves into a relatively large bowl, while consumer B serves into a relatively smaller bowl that still holds a nonbinding capacity. The gray circle in the fourth row of figure 2 represents the exact same target serving size both consumers typically serve if no biasing influence existed. The relatively larger gap between the edges of the serving size and the bowl—associated with diameter ratios smaller than 0.5—leads consumer A to encode and contrast the circle information of the serving size and the bowl when envisioning the target serving size into the large bowl (Nicolas 1995). As a result, we hypothesize she will perceive the target serving size to be smaller than its actual size (Pollack 1964) and compensate by overserving herself. The opposite is expected for consumer B. The relatively smaller gap between the edges of the serving size and the bowl—associated with diameter ratios larger than 0.5—leads consumer B to holistically pool and assimilate the circle information of the serving size and the bowl (Jaeger and Lorden 1980). As a result, we hypothesize he will perceive the target serving size to be larger than its actual size (Ward and Lockhead 1971) and compensate by underserving himself. Therefore,

H1: When the diameter ratio between the target serving size and the dinnerware is:

H1a: smaller than 0.5 (but larger than 0, which is typical with larger dinnerware), consumers serve more than the target serving size.

H1b: larger than 0.5 (but smaller than 1, which is typical with smaller dinnerware), consumers serve less than the target serving size.

When the diameter ratio approaches zero (i.e., the diameter of the serving size approaches zero) or one (i.e., the diameter of the serving size approaches the diameter of the dinnerware), perceptual biases disappear because there is no longer contrast and assimilation. This suggests that the perceptual biases for the entire range of diameter ratios can be presented by a sinus shape (see fig. 3). With these perceptual biases driving consumers' serving behavior, we expect to find an inverse pattern for serving biases.

If assimilation and contrast effects drive the hypothesized serving biases, existing research on these perceptual biases may be helpful in better understanding the underlying mechanism. For instance, both assimilation and contrast effects have been shown to be weakened by manipulating the color contrast of the inducing circles (Oyama 1960; Weintraub and Schenck 1986). Reducing the color contrast of the inducing circle (e.g., by using gray instead of black lines) lowers the salience of and thus participants' reliance on the circle when judging the test circle (Weintraub and Cooper 1972). This reduced reliance on the inducing circle has a corresponding effect on estimation biases (Coren and Girgus 1972) for circles as well as other figure-ground illusions (Li and Guo 1995). Thus, reducing the color contrast of the inducing circle—for instance, by placing a white plate on a white versus black tablecloth—should reduce assimilation and contrast effects, and serving biases, because consumers are more likely to ignore a low color-contrast-inducing circle.

H2: Reducing the color contrast between dinnerware and a tablecloth:

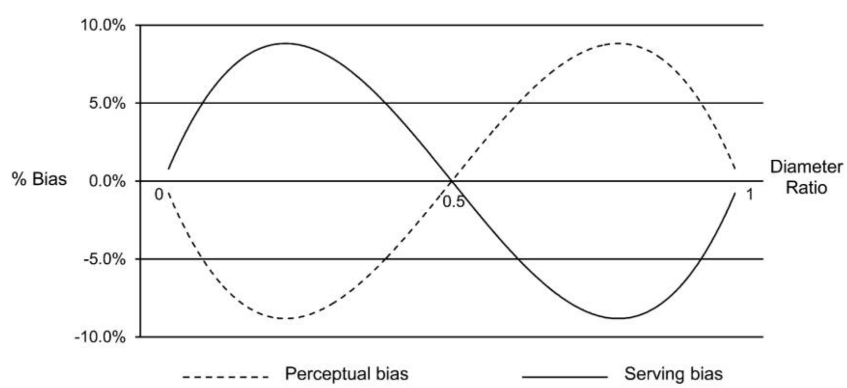
H2a: reduces overserving when the diameter ratio between the serving size and the dinnerware is smaller than 0.5 (but larger than 0), typically with larger dinnerware.

H2b: reduces underserving when the diameter ratio between the serving size and the dinnerware is larger than 0.5 (but smaller than 1), typically with smaller dinnerware.

Increasing people's attention to biasing stimuli may either exacerbate or attenuate the associated biases (Raghubir 2008). In the context of visual illusions, it has been shown that making people mindful of the stimuli involved, without making them aware of the actual influence of the stimuli, helps reduce the associated biases (Coren and Girgus 1978). The basic explanation of this effect of attention is related

FIGURE 3

RELATIONSHIP BETWEEN THE DIAMETER RATIO OF THE SERVING SIZE AND DINNERWARE AND THE ESTIMATION AND CORRESPONDING SERVING BIASES



to the movements of the eyes that, through continued inspection, allow for cognitive recalibration (Coren and Hoenig 1972).

H3: Attention to the target serving size and the dinnerware:

H3a: reduces overserving when the diameter ratio between the serving size and the dinnerware is smaller than 0.5 (but larger than 0), typically with larger dinnerware.

H3b: reduces underserving when the diameter ratio between the serving size and the dinnerware is larger than 0.5 (but smaller than 1), typically with smaller dinnerware.

Serving oneself food is a frequent activity that often occurs in distracting environments. Even if we found that making people more mindful of the target serving size and dinnerware would help attenuate serving biases, informing consumers that they simply need to pay attention when serving themselves may not be practical. Educating consumers specifically about the Delboeuf illusion and how it might bias serving may be a more feasible and effective strategy. That is, people are generally unaware of the effect of dinnerware size on serving behavior (Wansink and Van Ittersum 2003), let alone what causes it. While there is research to suggest that education may lead to overreactive overconsumption (Martin, Seta, and Crelia 1990), we expect that educating consumers about the Delboeuf illusion and its effect on serving behavior allows them to be more consciously involved and reduce or even eliminate the effects (Coren and Girgus 1972; Raghubir 2008). Research suggests that expertise reduces biases in a variety of domains (Shanteau 1992; Shanteau and Stewart 1992). Research on the effectiveness of educating people on the presence and effects of illusions also suggests that education reduces biases. However, Wansink and Van Ittersum (2005) report that while education reduces serving biases associated with pouring drinks in differently shaped glasses, it did not eliminate them.

H4: Education about the Delboeuf illusion:

H4a: reduces overserving when the diameter ratio between the serving size and the dinnerware is smaller than 0.5 (but larger than 0), typically with larger dinnerware, but it does not eliminate overserving.

H4b: reduces underserving when the diameter ratio between the serving size and the dinnerware is larger than 0.5 (but smaller than 1), typically with smaller dinnerware, but it does not eliminate underserving.

STUDY 1: THE EFFECT OF THE DELBOEUF ILLUSION ON SERVING BEHAVIOR

To test hypothesis 1, an experiment was conducted with 225 students (44.9% female) at the Georgia Institute of Technology. Their average age was 21.1 years (range 19–35).

Design and Procedure

Study 1 consisted of a between-subject design with seven bowl-size conditions. All participants were shown a target serving size of Campbell's tomato soup in a petri dish ($d = 9$ centimeters). The diameter of 9 centimeters closely resembles the diameter of one serving of soup in a standard soup bowl with a diameter of 18 centimeters. Next, participants were asked to serve soup with the exact same 9-centimeter diameter in one of seven randomly assigned bowls of different sizes. After a short break, participants were asked to determine to what extent the diameter of a pre-serving of soup in one of seven randomly assigned bowls was smaller or larger than the diameter of a target serving of soup ($d = 9$ centimeters).

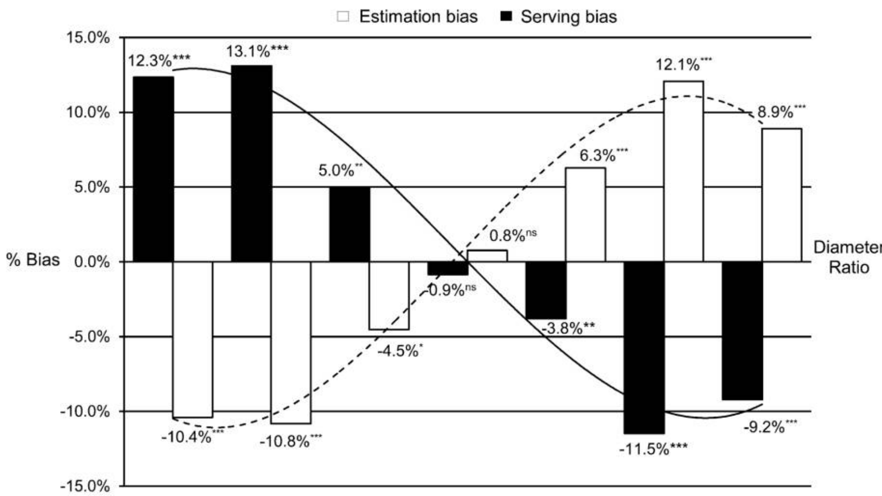
A professional potter was hired to create two sets of custom-made white bowls according to specification. The diameters of the bowls were determined based on the desired ratios between the target and the bowl diameter. Research has shown that the maximum under- and overestimation takes place at ratios of about 0.33 and 0.67. To capture these, the range of ratios studied was 0.25–0.75 (ratios beyond 0.75 and 0.25 result in unrealistically small and large serving sizes and bowls). We included one bowl that resulted in a diameter ratio of 0.50, which research suggests may be the transition point between under- and overestimation. We expected that the average bias for this bowl will be close to zero. The diameters and the ratios between the target diameter and the diameter of the bowl are included in figure 4.

Upon entering the lab, participants were informed that they would be presented with a petri dish of soup and asked to reproduce the target diameter of soup by pouring soup into a bowl. Participants were then guided to a station in the lab where they were presented with the 9-centimeter petri dish filled with tomato soup on a white tablecloth and asked to take a good look at the target diameter of soup. Next, participants walked to a different station, where they found one of the seven white bowls on a Bordeaux red tablecloth and a white hot pot (with a cap) that was filled with 40 ounces of tomato soup. Participants picked up the hot pot and poured tomato soup in the bowl until they felt that the soup in the bowl reached the same diameter as the target diameter. Next, participants were asked to take a seat while the researcher measured the diameter of the poured soup with a digital inside caliper and cleaned the bowl.

Following a short break, participants were guided to a different station in another part of the lab to start the perceptual task. After participants took a look at the target

FIGURE 4

ESTIMATION AND SERVING BIASES AS A FUNCTION OF THE DIAMETER RATIO OF THE TARGET SERVING SIZE AND BOWL SIZE



	Larger bowls			Control bowl		Smaller bowls	
	Bowl 1	Bowl 2	Bowl 3	Bowl 4	Bowl 5	Bowl 6	Bowl 7
d_{target} (cm)	9	9	9	9	9	9	9
d_{bowl} (cm)	36	25.7	20	18	16.4	13.8	12
Diameter Ratio	0.25	0.35	0.45	0.50	0.55	0.65	0.75
# Participants	31	31	35	32	32	33	31

NOTE.—The asterisks in the figure show whether the bias is significant ($\neq$ 0); * $p < .10$; ** $p < .05$; *** $p < .01$.

diameter of soup, they walked over to another station with a bowl of prepoured soup. The size of the bowl was randomized. The soup in the bowl had the exact same diameter as the target diameter. Next, participants were asked to determine whether and how much smaller or larger the diameter of the soup in the bowl was than the target diameter. They could use a magnitude scale to mark how much smaller or larger the diameter of the soup in the bowl was. After the participants were done, they were asked for their gender and age.

Results and Discussion

Analysis of variance revealed a significant main effect for bowl size ($F(6, 218) = 42.26$, $p < .01$). Consistent with hypothesis 1a, participants poured 8.2% less in the three smaller bowls (diameter ratios >0.5 and <1) than the target serving size ($t(95) = -10.49$, $p < .01$). As illustrated in figure 4, participants poured 9.9% more in the three larger bowls (diameter ratios <0.5 and >0), thereby confirming hypothesis 1b ($t(96) = 8.89$, $p < .01$). Those who poured in the control bowl (diameter ratio = 0.5) poured an insignificant 0.9% less than the target serving size ($t(31) = -.91$, $p > .10$). While technically we test the effect of diameter ratios, for readability purposes we implicitly refer to differences in diameter ratios based on larger versus smaller bowls (noting that the target serving size is constant across conditions).

If the Delboeuf illusion drives these pouring biases, a reversal should be found for the estimation biases. The results confirm this. First, analysis of variance revealed a significant main effect for bowl size ($F(6, 218) = 15.9$, $p < .01$). Participants perceived the diameter of the pre-served serving size in the smaller bowls to be 8.9% larger than the diameter of the target serving ($t(93) = 7.93$, $p < .01$), while the opposite is found for the larger bowl (−8.6%, $t(91) = -5.18$, $p < .01$). Participants estimating the diameter of the pre-served soup in the control bowl overestimate by an insignificant 0.8% ($t(38) = 0.60$, $p > .10$).

To gain a more detailed understanding of the mechanism that drives these main effects, we next examined whether and how these serving and estimation biases relate to the ratio between the target and bowl diameters (as visualized in fig. 3). First, consistent with expectations, the results (see fig. 4) suggest that the relationship between the diameter ratios and the serving biases follows a sinus shape. As would be expected, this shape is reversed for estimation. Both relationships can be captured almost perfectly by a three-degree polynomial model (estimation bias: $R^2 = .99$; serving bias: $R^2 = .98$). Furthermore, the polynomial model significantly outperforms the linear model for both estimation bias ($\Delta F(2, 3) = 120.7$, $p < .01$) and for serving bias ($\Delta F(2, 3) = 40.2$, $p < .01$). In both polynomial models, all three coefficients are significant ($p < .01$). Second, the estimation and serving biases follow an inverse pattern, suggesting that perceptual biases drive the serving biases. Finally, the results suggest that these biases are largest when the ratios between the target and bowl diameter approach 0.33 and 0.67, respectively, and the biases approach zero when the diameter ratio approaches 0.50.

The results show a countercyclical relationship between estimation biases and serving biases. This shows a double jeopardy of bowl size: while big bowls lead to overserving, small bowls lead to underserving for the same reason. This notion of assimilation and contrast is further explored in study 2 by manipulating contextual contrast.

STUDY 2: THE EFFECT OF COLOR CONTRAST BETWEEN DINNERWARE AND TABLECLOTH AND THE DELBOEUF ILLUSION ON SERVING BEHAVIOR

The results of study 1 suggest that assimilation and contrast cause people to under- and overserve on smaller and larger bowls, respectively. To provide additional evidence for the proposed mechanism driving these serving biases and examine hypothesis 2, study 2 manipulated the color contrast of the dinnerware against its background. It involved 47 Georgia Tech students (40.4% female) with an average age of 21.7 (range 18–26 years).

Design and Procedure

Study 2 consisted of a 2 × 2 design where we manipulated diameter ratio with bowl size (small vs. large) and color contrast (low vs. high) as within-subject experimental factors. All participants were shown a target serving size of cereal ($d = 10.5$ centimeters, 15 grams of cereal) and asked to reproduce this circle on two small ($d = 17.0$ centimeter) and two large plates ($d = 26.4$ centimeter) with an identical depth (1.75 centimeter) by serving themselves cereal with the same diameter. In the context of pouring or serving food, one way that color contrast might naturally vary would be through the contrast between the plate and its surroundings—this could be the color of the table or the tablecloth. To manipulate the color contrast of the inducing circle (plate), we placed white plates on a white tablecloth (low color contrast) versus a black tablecloth (high color contrast). The four conditions were spread out over four adjacent labs. The order was randomized, and no order effects were found. The weights of all serving sizes were recorded.

Results and Discussion

Analysis of variance revealed a significant main effect for plate size ($F(1, 43) = 4.37$, $p < .05$) and a significant interaction effect between plate size and color contrast ($F(1, 43) = 6.22$, $p < .05$). Between-subject tests using the data of the first serving task further confirmed these findings. Planned comparisons showed that participants in the high color-contrast condition served 9.8% more than the target serving size on the larger plate ($t(46) = 5.27$, $p < .01$) and 13.5% less than the target serving size on the smaller plate ($t(46) = 5.66$, $p < .01$; see fig. 5). The reduction in color contrast significantly reduced overserving on large plates (9.8% vs. 0.3%; $F(43) = 3.98$, $p < .05$), thereby confirming hypothesis 2a. Consistent with hypothesis 2b, the reduction in color contrast reduced underserving on small plates (−13.5% vs. −4.7%; $F(43) = 4.06$, $p < .05$). Note that a significant underserving bias is still observed in the low color-contrast condition (−4.7%; $t(46) = 3.24$, $p < .05$). The effect of plate size remains significant in the low color-contrast condition ($F(1, 46) = 7.83$, $p < .01$). Between-subject tests using the data of the first task further supported these findings.

Consistent with existing literature that suggests that the perceptual biases caused by assimilation and contrast can be mitigated by reducing the color contrast of the inducing circle and its background, the results of study 2 demonstrate the corresponding effects of this strategy on actual serving biases. The results corroborate that assimilation and contrast facilitate perceptual biases that subsequently result in opposing serving biases.

STUDY 3: THE EFFECT OF ATTENTION AND THE DELBOEUF ILLUSION ON SERVING BEHAVIOR INTENTIONS

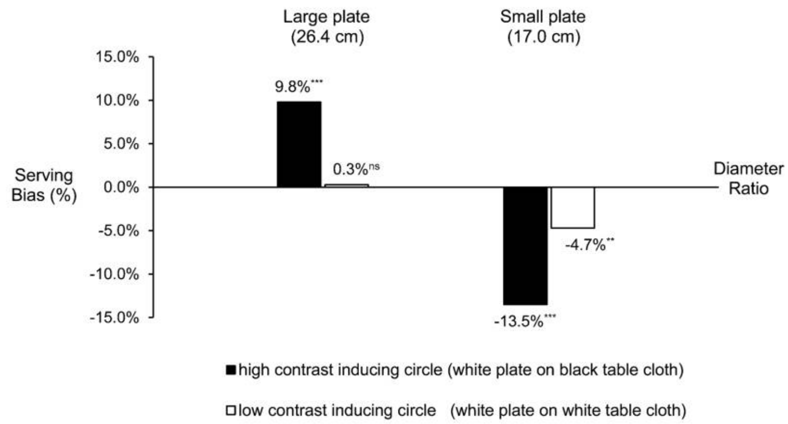
To strengthen and generalize the results of studies 1 and 2 and test hypothesis 3, a third experiment was conducted with 91 students (42.2% female) at the Georgia Institute of Technology. Their average age was 21.6 years (range 18–27).

Design and Procedure

Study 3 involved a 2 × 2 design where we manipulated diameter ratio with plate size (small vs. large) and one's degree of focused attention (low vs. high) as within and between-subject experimental factors, respectively. All participants were shown a target serving size of cereal ($d = 10.5$ centimeters, 15 grams of cereal) and asked to draw a circle with the same diameter as the target serving size on a smaller ($d = 17.0$ centimeters) and larger plate ($d = 26.4$ centimeters) with an identical depth (1.75 centimeters), both of which were presented in different stations in the lab. Half of the participants were asked to enter the station, take a brief glance at the stimuli (2 seconds or less), and then draw the circle (control condition). The other half were asked to take 1 minute (using a 1-minute timer) to inspect both stimuli

FIGURE 5

LOW COLOR CONTRAST BETWEEN PLATE AND TABLECLOTH REDUCES OVER- AND UNDERSERVING ON LARGER AND SMALLER PLATES



NOTE.—The diameter of the target serving size is 10.5 centimeters; * $p < .10$; ** $p < .05$; *** $p < .01$.

and then draw the circle. The diameters of the serving circles they drew were calculated by averaging two orthogonal diameter measures ($r = .98$).

Results and Discussion

Analysis of variance revealed a significant interaction between plate size and attention ($F(1, 85) = 16.27$, $p < .01$). Planned comparisons showed that participants in the control condition served 8.3% more than the target serving size on the larger plate ($t(43) = 6.51$, $p < .01$), thereby confirming hypothesis 1a. In line with hypothesis 1b, participants served 11.2% less than the target serving size on the smaller plate ($t(43) = 9.68$, $p < .01$).

As figure 6 shows, attention significantly reduced the Delboeuf illusion's effect on serving behavior from a −11.2% + 8.3% = 19.5% serving bias to a −7.2% + 1.0% = 8.2% serving bias. Free inspection of the stimuli reduced both the assimilation associated with smaller plates ($F(1, 85) = 4.71$, $p < .05$) and the contrast associated with larger plates ($F(1, 85) = 6.58$, $p < .05$). Consistent with hypothesis 3a, attention reduced overserving on larger plates (1.0% ≈ 0; $t(46) = .56$, $p > .10$). In line with hypothesis 3b, attention reduced underserving on smaller plates from 11.2% to 7.2% ($t(43) = 2.57$, $p < .05$).

Making people mindful of the target serving size and plate size reduces the effects of the Delboeuf illusion. Despite these promising results, one could question the practicality of asking consumers to pay close attention when they serve themselves. A more effective strategy may be to explicitly educate consumers about how the Delboeuf illusion biases behavior. To examine this and test hypotheses 4a and 4b, study 4 was conducted.

STUDY 4: THE EFFECT OF EDUCATION AND THE DELBOEUF ILLUSION ON SERVING BEHAVIOR

To test whether education about the Delboeuf illusion eliminates perceptual biases, an experiment was conducted with 101 students (41.6% female) at the Georgia Institute of Technology. Their average age was 21.6 years (range 18–39).

Design and Procedure

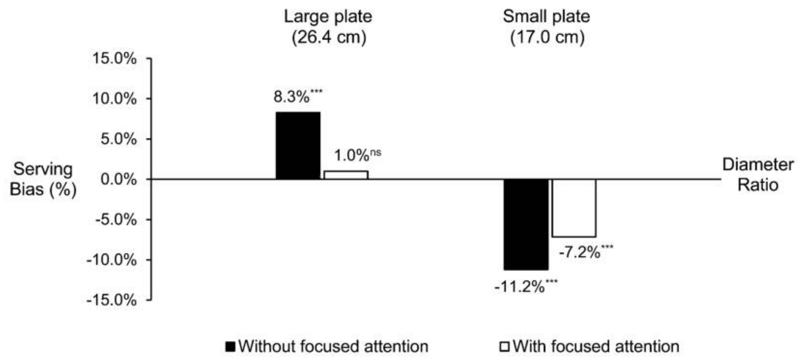
Study 4 consisted of a 2 × 2 design where we manipulated diameter ratio with plate size (small vs. large) and education (uneducated vs. educated) as within and between-subject experimental factors, respectively. Participants were presented with the target serving size of cereal ($d = 10.5$ centimeters, 15 grams of cereal) and asked to serve themselves the exact same amount of cereal on both a smaller (17.0 centimeters) and a larger plate (26.4 centimeters) with an identical depth (1.75 centimeters; presented in different stations in the lab). Prior to the serving task, half the participants were informed about the Delboeuf illusion—the biases were explained and visualized—and its effect on serving behavior. The weights of all serving sizes were recorded.

Results

Analysis of variance revealed a significant interaction effect between plate size and education ($F(1, 99) = 6.65$, $p < .05$). Planned comparisons revealed that education reduced the effect of the Delboeuf illusion on serving behavior from a −10.6% + 7.1% = 17.7% serving bias to a −4.4% +

FIGURE 6

ATTENTION REDUCES SERVING BIASES



NOTE.—The diameter of the target serving size is 10.5 centimeters; * $p < .10$; ** $p < .05$; *** $p < .01$.

4.3% = 8.7% serving bias (see fig. 7). Plate size influenced serving behavior, but less so among educated participants.

Consistent with hypotheses 4a and 4b, education reduced both the assimilation associated with smaller plates ($F(1, 99) = 5.97$, $p < .05$) and the contrast associated with larger plates ($F(1, 99) = 4.01$, $p < .05$). Furthermore, in accordance with expectations, education does not eliminate overserving on larger plates ($4.3\% > 0$; $t(48) = 2.50$, $p < .05$) nor underserving on smaller plates ($-4.4\% < 0$; $t(48) = -2.11$, $p < .05$).

Discussion of Studies 1–4

The results of studies 1–4 suggest that the well-established contrast and assimilation biases that constitute the Delboeuf illusion have corresponding influences on serving behavior. The results soundly refute the notion that reported dinnerware-size effects represent a main effect (Wansink et al. 2006). Instead, the seemingly main effect of dinnerware size is the joint outcome of two opposing forces that lead consumers to serve more than a target serving size on large dinnerware and less than a target serving size on small dinnerware.

Different food intake studies in the field have shown results consistent with what the Delboeuf illusion would predict. First, Wansink et al. (2006) demonstrated that when 85 nutrition experts were given a larger bowl, they served themselves 31.0% more (6.3 vs. 4.8 ounces, $F(1, 80) = 8.05$, $p < .01$). In a second field study, involving 113 overweight teenagers at a 6-week health and fitness camp in New Hampshire, the authors found that those given larger bowls served 27.8% more cereal at breakfast than those given smaller bowls (49.6 vs. 38.8 grams; $F(1, 112) = 27.24$, $p < .01$). In a third study, similar results were found with 81 adult jazz musicians attending a 3-day jazz improvisation camp in western Massachusetts. Those who were given larger bowls served 32.5% more cereal than those given smaller bowls (70.7 vs. 51.6 grams; $F(1, 80) = 16.54$, $p < .01$). Consistent with the empirical generalization that people, on average, will consume around 92% of what they serve themselves (Wansink 2006, 59), 97.3% of the diners in these three field studies consumed all they had served.

Despite the fact that these three field studies demonstrate that the size of dinnerware influences serving and consumption behavior, they do not provide direct evidence that the Delboeuf illusion is actually driving these results. To more closely examine whether the robustness of the Delboeuf illusion holds up in real-life serving situations, we conclude with a field experiment involving adults who served themselves lunchtime pasta during a college reunion.

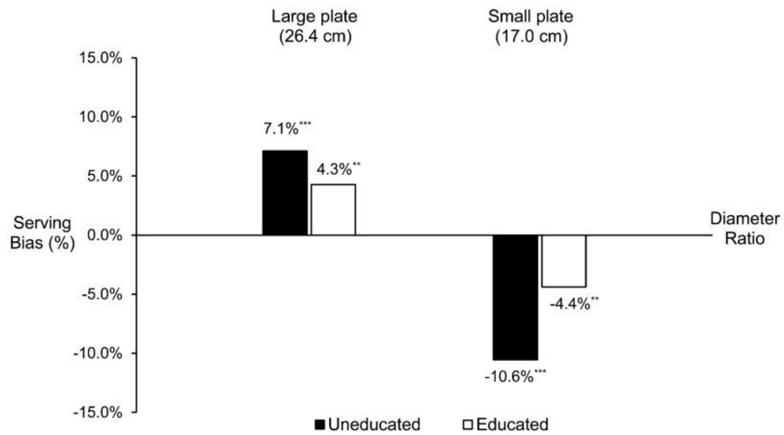
STUDY 5: THE EFFECT OF COLOR CONTRAST BETWEEN FOOD AND DINNERWARE AND THE DELBOEUF ILLUSION ON SERVING BEHAVIOR

On the first day of a college reunion in upstate New York, we directed 60 (30 female) lunch goers to a buffet table where they served themselves pasta that was premixed with a red tomato sauce or to a buffet table where they served themselves pasta that was premixed with a cream-based white Alfredo sauce. At each of these tables, they were randomly given a white plate or a dark red plate.

If the Delboeuf illusion influences serving behavior as studies 1–4 suggest, we would expect to find that lunch goers serving themselves white (red) sauce pasta on a white (red) plate serve a different amount than those serving white (red) sauce pasta on a red (white) plate. The rationale for this is that differences in color contrast between the pasta and the plate influence the Delboeuf illusion, depending on the size of the plate. Study 2 showed that reducing the color

FIGURE 7

EDUCATION OF THE BIAS MITIGATES BUT DOES NOT ELIMINATE SERVING BIASES



NOTE.—The diameter of the target serving size is 10.5 centimeters; * $p < .10$; ** $p < .05$; *** $p < .01$.

contrast of the inducing circle relative to its background (white plate on a white tablecloth) reduces the magnitude of the Delboeuf illusion. However, reducing the color contrast of the test circle relative to the inducing circle (e.g., white-sauce pasta on white plate) has shown to increase the magnitude of the Delboeuf illusion (Weintraub and Cooper 1972) as the low color-contrast test circle increases the need for the visual comparisons. This will increase one's tendency to overserve onto larger dinnerware and to underserve onto smaller dinnerware. This is confirmed in a lab experiment resembling study 2. Participants serving white cereal on a small white plate underserved themselves more than participants serving dark cereal (−19.4% vs. −12.0%; $F(1, 86) = 7.1$, $p < .01$). Likewise, participants serving white cereal on a large white plate overserved themselves more than those serving dark cereal (17.3% vs. 9.8%; $F(1, 86) = 5.7$, $p < .05$).

Design and Procedure

Upon entering the serving area, participants were randomly led to one of two buffet tables. One table only offered pasta in a white cream-based Alfredo sauce; the other table only offered pasta in a red tomato-based sauce. Participants were not aware that the two tables offered different flavors (colors) of pasta sauce. Once in line at the buffet, each participant was randomly given either a large dark red plate or a white plate of equal diameter (27.3 centimeters). Plate size was kept constant to minimize the chance of lunch goers becoming suspicious. We chose larger plates to examine whether using high-contrasting larger dinnerware could help consumers reduce their food intake compared to those using low-contrasting larger dinnerware.

Half of the lunch goers served themselves pasta that was premixed with a white cream-based Alfredo sauce while the other half served themselves pasta that was premixed with a red tomato-based sauce. After they finished serving themselves, their pasta was weighed by hidden scales, and they then continued through the line to serve themselves a beverage and dessert.

According to the Food Guide Pyramid and the Diabetic Exchange System, a serving of pasta is one-half cup of cooked pasta (114.3 grams), which closely resembles the size of a fist ($d = 8.3$ centimeters). The diameter ratio of this serving size and the plate ($d = 27.3$ centimeters) is 0.30, which stimulates contrast and thus overserving under high color-contrast conditions (see study 1). In accordance with the research by Weintraub and Cooper (1972), we expect participants in the low color-contrast conditions (white-sauce pasta on white plate; red-sauce pasta on red plate) to overserve themselves significantly more pasta than those in the high color-contrast conditions.

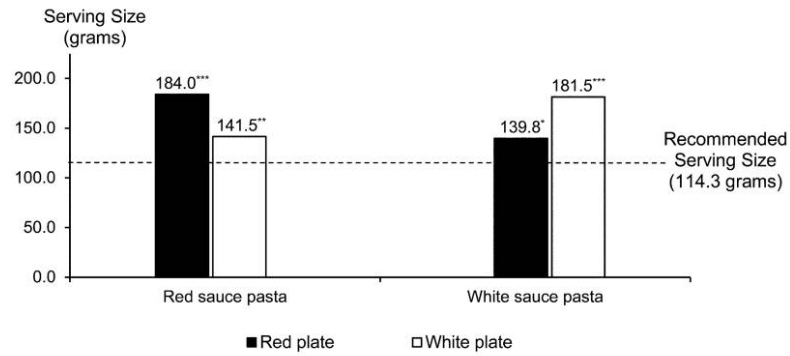
Results and Discussion

Consistent with expectations, participants in the low color-contrast conditions overserved significantly more pasta than those in the high color-contrast conditions (182.7 vs. 140.6 grams; $F(1, 58) = 7.92$, $p < .01$). Figure 8 illustrates that people overserved themselves more pasta when given the same color plate (i.e., white-sauce pasta on a white plate, or red-sauce pasta on a red plate) than when given a contrasting color plate (i.e., white-sauce pasta on a red plate, or red-sauce pasta on a white plate).

The serving sizes in the two low color-contrast conditions did not differ. Lunch goers overserved as much red-sauce pasta on red plates as they did white-sauce pasta on white plates (184.0 vs. 181.5 grams; $F(1, 27) = .01$, $p > .20$).

FIGURE 8

HIGH COLOR CONTRAST BETWEEN PASTA AND A PLATE REDUCES OVERSERVING AT A COLLEGE REUNION



Note.—* $p < .10$; ** $p < .05$; *** $p < .01$.

Similarly, the serving sizes in the two high color-contrast conditions did not differ. Lunch goers overserved as much red-sauce pasta on white plates as they did white-sauce pasta on red plates (141.5 vs. 139.8 grams; $F(1, 29) = .23$, $p > .20$). Consistent with earlier findings, in both conditions, people overserved themselves relative to the recommended serving size (141.5 grams > 114.3 grams; $t(16) = 2.05$, $p < .05$; 139.5 vs. 114.3; $t(13) = 1.83$, $p < .05$).

This important field study shows converging results with what was found in the lab studies. In combination, these findings underscore the behavioral consequences of perceptual biases. Over time and with repeated meals, the gradual impact on one's weight gain would be significant.

GENERAL DISCUSSION

Despite the apocryphal contention that dinnerware size influences serving behavior and food consumption, until now it was unclear why this might be. This lack of understanding has hindered the systematic research of how this—and a wider range of environmental cues—might influence serving behavior, and it precluded the ability to reconcile contradictory findings.

Importantly, findings reported here empirically demonstrate that the Delboeuf illusion may explain why and how dinnerware size influences serving behavior. For nearly 150 years, the Delboeuf illusion has been regarded as robust, but "of little practical value" (Coren and Girgus 1978). In the context of serving behavior, however, it takes on an undiscovered dimension of everyday importance. By introducing the Delboeuf illusion as a possible explanation and extending it from the perceptual to the behavioral domain, the studies have shown how the illusion biases serving size perceptions, serving behavior, and consumption. Whereas contrast effects explain why consumers tend to overserve when using larger bowls and plates, assimilation effects explain why they also tend to underserve when using smaller ones.

These results uniquely suggest a range of characteristics that could moderate the influence of external cues (see table 1). It was found that attention and education may reduce the overserving (underserving) biases associated with serving on larger (smaller) bowls and plates. Furthermore, while reducing the color contrast between the dinnerware and its background may help reduce over- and underserving biases, increasing the color contrast between the food and the dinnerware actually may accomplish this as well. We conclude that the Delboeuf illusion offers a key explanation as to why and when the size of dinnerware influences serving-size perceptions, serving behavior, and consumption.

Theoretical Implications

Environmental cues—such as dinnerware size—significantly bias food intake. By extending the Delboeuf illusion from the perceptual to the behavioral domain, we help refute the notion that there are separate visual pathways for perception versus action that prevent visual illusions from having behavioral consequences (Franz et al. 2000). Research on the behavioral implications of visual illusions has been mixed. This lack of consistency has been used as supporting evidence that there may be separate visual pathways for perception and action (Franz et al. 2000). However, a growing body of research refutes this idea, suggesting—but not showing—that visual illusions can have behavioral consequences (Watt, Bradshaw, and Rushton 2000). Finding a context in which we empirically validate the behavioral consequences of the Delboeuf illusion constitutes a significant theoretical contribution to this literature. Importantly, these results not only corroborate the idea that the Delboeuf illusion may explain why and how dinnerware size causes

TABLE 1

MODERATORS OF OVERSERVING AND OVERCONSUMPTION

Moderating characteristics	Impact on serving behavior	Related references
Contrast-level between the stimuli	Low color-contrast between the dinnerware and the tablecloth reduces overserving on larger plates and underserving on smaller plates Low color-contrast between the food and the dinnerware increases overserving on larger plates	Weintraub and Cooper 1972; Weintraub and Schenck 1986
Attention level of the server	Attention reduces overserving on larger dinnerware and underserving on smaller dinnerware	Coren and Girgus 1978
Education level of the server	Education reduces overserving on larger dinnerware and underserving on smaller dinnerware	Coren and Girgus 1978

serving biases; they also offer opportunities for consumers and companies to cope with dinnerware-size-induced biases.

Understanding this mechanism can enable researchers to identify and examine possible moderating variables that may explain inconsistencies reported in the literature. For instance, referring back to table 1, people who are paying little attention to how much they serve might be particularly susceptible to being biased by the size of their dinnerware. For instance, this would be more likely to occur when people at a celebratory ice cream social serve themselves vanilla ice cream into a white bowl than when they serve themselves oatmeal every morning in a distraction-free kitchen. As an example, when comparing the results of Wansink et al. (2006) and Rolls et al. (2007), the former studied serving biases during a distracting afternoon ice cream social, while the latter research was conducted with adults repeatedly eating lunch in an isolated cubicle with no distractions. Indeed, the distractions found in natural environments should also lead a person to spend more time focused on cues (such as dinnerware size) and less focused on the absolute amount served (Wansink and Van Ittersum 2007). Indeed, the field studies of teenage dieters and jazz musicians showed that both groups served an average of 30% more breakfast cereal when the size of their bowls was doubled (15.2 to 21.4 centimeters in diameter). Finally, even the color contrast between the dinnerware and the table or the food and the dinnerware has an important bias that can lead to inconsistencies. It would be valuable if future work in this area noted the color of food, plates, and the background of the service area where a person served themselves.

Over 150 years ago, the Delboeuf illusion was thought to be of little practical use. The findings here suggest that it could be highly relevant in considering new ways to operationalize variations in dinnerware design. Whereas these studies only varied the size and color of the dinnerware, there are a wide range of design elements that provide opportunity for more extensive theory development as well as have promising applications. These include:

1. How does the diameter of the verge ring (the point where a plate or bowl's interior surface goes from flat to sloped) influence perceptions and serving behavior?
2. Does the diameter band on the lip of a bowl or plate bias perceptions?
3. Which designs or colors of a plate or bowl's ridge influence size estimations?

Limitations and Future Research

These results demonstrate how the size of dinnerware people use to serve themselves may significantly influence how much food they consume on a day-to-day basis. They also importantly document the vulnerability of children. What makes this especially troublesome is that consumption norms that develop early in life may continue to influence consumers throughout their lives.

One issue with perceptual biases is that they appear hardwired to the point of generally being nonconscious (Folkes and Matta 2004). Because of this, it is difficult to pinpoint the underlying process that causes dinnerware size to bias serving-size perceptions, serving behavior, and consumption. During debriefings, participants described that they first approximated how much they needed to serve to reach the target serving size onto their plate. Focusing on the serving diameter as opposed to the serving height of the food (Krider, Raghubir, and Krishna 2001), they then noted that they served themselves until they served their target serving size. Future lab research can continue to develop and experiment with relevant process measures and boundary conditions. However, this must be balanced with the risk of obtrusiveness and artificiality, which may have biased some previous studies in clinical settings or in lab experiments.

To expand our understanding of the effects of the Delboeuf illusion in real life, future research could examine whether and how the perceptual and serving biases affect postconsumption satisfaction with food products. The effect of the Delboeuf illusion in social settings, where serving norms may influence serving behavior, may provide additional insights into factors that may reduce plate-size susceptibility. Finally, a closer examination of some of the boundary conditions may be warranted. While research has shown that the Delboeuf illusion is robust in labs and in the field studies, it is important to note that none of these individuals have gone through extended periods of food deprivation. When a person has experienced food shortages or food insecurity—due to poverty, famine, imprisonment, or natural disaster—the influence of these illusions may be less robust.

It has frequently been asked whether the color of dinnerware influences serving. This question presupposes that there is one best color dinnerware to reduce overeating. Importantly, our findings show that it is not the color of dinnerware that makes the difference; it is the color contrast between the color of the food and the color of the plate, or the color of the plate and the color of the table. This twist helps explain why past investigations of color have not been successful. If the contrast of the food and the size of the plate were not taken into account, results would be inconsistent across different foods, plate colors, and backgrounds.

Consumer-Related Implications

It is often assumed that education and vigilance are effective tools to reduce one's consumption and combat obesity. With dinnerware-size-induced biases, our results are less sanguine. Attention and education reduced but did not eliminate these biases. Educating people and stimulating them to be vigilant may temporarily reduce their biases, but in similar illusory contexts, even practice trials and immediate reminders were unable to erase them.

Given the robustness of dinnerware-size-induced biases, it may be best to simply encourage people to replace larger bowls and plates with smaller ones. This research demonstrates that replacing larger dinnerware with smaller dinnerware reduces the likelihood of overserving (and actually increases the likelihood of underserving) relative to a personal consumption norm. Importantly, based on what has been suggested elsewhere, this decrease in intake may not lead to decreased satisfaction. It could simply lead consumers to satisfy their hunger while unknowingly eating less food.

In cases where replacing larger dinnerware is difficult, the color of the dinnerware may offer opportunities to reduce consumption. Someone who owns larger dinnerware in different colors may want to choose the color that highly contrasts with the food he is serving to minimize overserving biases. Furthermore, consumers could still help control their serving behavior by selecting tablecloths that minimize the contrast with the dinnerware. By minimizing the color contrast between the dinnerware and the tablecloth, overserving biases may reduce.

An important danger to note is with individuals who have eating disorders or who otherwise need to eat more to maintain their health (such as the elderly). The tendency of these people would be to take smaller dinnerware. Yet just as larger dinnerware leads to overserving (compared to what would be typical), smaller dinnerware leads to underserving. The result is that smaller dinnerware would lead these vulnerable populations to serve and consume even less than they otherwise would. One possible solution is to provide these people with larger dinnerware. Alternatively, provide them with dinnerware that contrasts with the food, or replace the tablecloth with one that minimizes the color contrast with the dinnerware.

While replacing larger dinnerware with smaller dinnerware reduces how much all consumers eat, it may have a disproportionate influence on certain segments of consumers. Consider children. When children serve themselves, they underserve themselves the most when serving onto smaller plates (Van Ittersum and Wansink 2007). In addition, the smaller norms suggested by smaller dinnerware could lead to healthier consumption benchmarks for children as they grow. Replacing larger dinnerware with smaller dinnerware will reduce plate size and personal consumption norms, something that might benefit children for the remainder of their lives (Wansink and Van Ittersum 2007).

Food costs and food waste can have a nontrivial impact on household budgeting. In addition to helping control food consumption, smaller dinnerware also may reduce household food waste. It could even occasionally help a parent stretch leftovers or manage the perception that there is plenty to eat when an unexpected guest arrives for dinner.

In contrast to most of the prior discussion, there may be instances when it is beneficial to replace smaller with larger dinnerware. For instance, a parent may want his or her child to eat more hot oatmeal, and a dietician may want nursing home patients to consume more stew or applesauce in the cafeteria. In these cases, larger bowls and plates are likely to encourage more consumption than the smaller ones that might be currently used. Under these circumstances, the added capacity of the larger dinnerware is immaterial. The increased size, however, does help induce a serving bias that unknowingly stimulates people to serve more than they otherwise would have. Just as nutrition gatekeepers (Wansink 2003) can use the size of dinnerware to help manage how much those in their care eat, dieters can use a similar strategy on themselves. As a general rule of thumb, the size of dinnerware should vary proportionally with the healthfulness of what is being consumed—small plates for entrees and large plates for salads.

Consumers eat from plates and out of bowls without thinking how their size proportionally influences how much they serve and eat. The solution to our tendency to overeat from larger plates and bowls is not simply education. In the midst of hardwired perceptual biases, a more straightforward action would be to simply eliminate large dinnerware—replace our larger bowls and plates with smaller ones. Alternatively, use bowls and plates that contrast with the color of the food being served. For emphasis, it may be easier to change our personal environments than to change our minds. For some people, however, this is critical.

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