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MindFull: Tableware to Manipulate Sensory Perception and Reduce Portion Sizes

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Abstract

Rising obesity levels across the world are a major threat to health, well-being and the economy. Reducing the amount we eat is difficult. This is partly because consciously controlling our eating typically increases the amount we eat. The paper presents the MindFull tableware—a new design for tableware to help people to reduce portion sizes effectively and unconsciously. MindFull designs exploit a range of features of our sensory perception identified from psychological research literature. Initial experiments show encouraging results for the design and suggest several directions for future development, research and applications for the design findings.

Keywords: perception, portion size, tableware, sensory illusions, design psychology

1. Introduction

Psychology's understanding of sensory errors and our eating experiences when combined with design can be used to help people control their portion sizes. This paper reports on some relevant aspects of psychology research, how they can be applied to the design of tableware, along with the results of preliminary tests of the tableware (**Figure 1**).

The worldwide prevalence of obesity has more than doubled since 1980 due to the increased availability of calorie dense food and the decreased need for physical activity. The increase in obesity is pulling on our society's resources both directly and indirectly. Cawley and Meyerhoefer [1] estimate just over 20% of US health expenditures are on obesity-related illness costing \$209.7 billion. Also, those who are obese are more likely to miss days of work, costing \$4.3 billion in absentee-related costs [2]. Many also struggle to perform some job demands, resulting in 4.2% loss in productivity in jobs such as manufacturing [2]. Obesity and depression are also strongly linked [3] adding to individuals' pain.



Figure 1. MindFull tableware, photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

There are many strategies to lose weight: various exercise programmes, diets including low fat and low carbohydrate diets and reductions in meal frequency, to name a few. In the end, weight loss works if energy intake is less than energy output. One of the simplest and most effective ways of doing this is through the reduction of portion sizes [4]. Our standard portion sizes have been consistently increasing which makes it easy to mindlessly overeat [5]. Portion control can be hard, particularly when adherence requires attention. Unfortunately, consciously restraining eating makes you more likely to eat the food you are purposely avoiding and increases the risk of bingeing [5, 6]. However, when people are unaware, smaller portions have very little effect on reported satiety [7]. Portion size reduction lends itself to long-term adherence, particularly for people who are not actively restricting their food intake.

Importantly, outside extreme levels of hunger, satiety is more strongly influenced by our expectations and our memory than physiological signals [8]. There is a strong body of evidence supporting the impact of memory on our appetite and subsequent food intake. Simply remembering a recent meal can reduce how much we eat during the next meal [9, 10]. Our implicit memory of recent eating strongly affects satiety. Patients with anterograde amnesia would eat their normal meal up to three times in a row, when the control group ate one [11]. In addition, many studies have confirmed the effectiveness of recalling a recent meal, see Refs. [10, 12] for meta-analyses. The same was found in Wansink's bottomless soup bowl study, where bowls could self fill and empty [13]; regardless of the amount participants consumed, satiety was governed by how much they perceived they had eaten.

Expectations are equally as important as memory: if we expect a meal will satisfy then usually it will [14]. Labelling food as high calorie lets people feel fuller and eat less than the same food with no labelling [15]. Furthering this line of inquiry, Brunstrom et al. [16] tested whether expected satiety could be manipulated without drawing attention to it. Participants were shown either a large or small quantity of fruit under the guise of checking for allergies. They were given identical-sized smoothies. However, those who saw the larger amount of fruit felt more satisfied and reported lower hunger levels throughout the 3 hours of testing. Our expectations of satiety have little relation to actual calorie content: high-fat or dense-calorie foods are expected to be less filling per calorie than carbohydrates. For example, potatoes were rated as five times

more filling than cashew nuts [17]. Because the volume-to-calorie ratio differs between foods, judging how filling food will be is difficult. Past experiences make it easier to accurately judge food that we are familiar with and have eaten to a level of fullness [17]. For unfamiliar foods and meals with several different foods, we tend to rely on a volume heuristic to judge quantity [18]. There is also a high correlation between familiar foods and satiety [17, 19].

These findings led the team of four undergraduate students, supervised by the author, to focus on creating designs which would manipulate users' expectations of the amount of food they were eating and help them pay attention when eating. To drive design decisions, the team chose to investigate common sensory perception errors.

Our sensory perception of volume is important when judging portion size. To enable faster thinking, our cognitive processes rely on heuristics of many kinds to quickly understand the world around us. From an early age, people estimate volume using height, width and length [20]. For young children to be accurate, the forms must be simple, as shown through Piaget's work with volume consistency [21, 22]. Surprisingly, our volume estimation of complex forms only becomes slightly better with experience [20]. Volume accuracy is much better with rectilinear and cylindrical forms [22, 23]; people find it much harder to judge the volume of complex and curvilinear forms we are unfamiliar with. The design implications are to cause perception errors in volume estimation by using non-standard, complex forms.

Nonvisual senses are important. When containers are tall and thin visually, people tend to misjudge them as having a greater volume. But when using haptic senses, the bias is reversed [24]. This could be because, in the hand, the width dimension is more prominent compared to the height [25]. This same reversal was found in Pechey et al.'s investigations into the effect of 'glass shape' on volume judgments of wine [26]. Designs must consider both visual and haptic cues, using forms that feel wide, yet are visually perceived as large.

Weight impacts on volume perception. Heavier containers are perceived as larger [30]. Piqueras-Fiszman and Spence [27] found participants expected food to be more filling when presented in heavier but visually identical containers. Intriguingly, it is not only just straight mass that changes perception but also the effort exerted in our muscles [28]. It is important to note different manipulations allowed different cues to become more salient; holding an object to throw lets people feel more than just lifting it up and down, thus allowing the brain to account for the sensory input [28]. There are some odd aspects to weight heuristics: even when we have experience with an object, if it is large but light, we will still exert extra force when manipulating it [29]. If weight is being used to manipulate perception, the handling of the object must be considered.

The size-contrast illusion is also important: our size judgement is altered by comparisons with contextual cues. When applied to eating, participants (even nutrition experts) serve themselves more ice cream in a larger bowl than a small bowl [30]. In *Mindless Eating* [5], Wansink discussed experiments showing larger plate size can affect perception of portion size. However, Penaforte et al. [31] did an experiment with identical portion sizes of plain pasta on different sized flat plates and found plate size did not make any difference. Our team found these findings provocative, as they did not fit with previous literature. We postulated two possible explanations for the results. Firstly, pasta is a very familiar food to many people, making judging the portions easier. Secondly, a pile of pasta on a flat plate is a simple shape, so simple cognitive judgments can accurately estimate portion size. This highlights the need for complex and deceptive forms.

Three other relevant points emerged from the research. A smooth cube is perceived as being larger than a rough one [22]. Reducing eating speed results in lower food intake [12]. A cute/baby schema helps to narrow and focus attention during unrelated tasks [32]. All of these could be factored into a design.

2. Design

Many current designs overtly address the issue of portion control. For example, they simply visualise how big portions should be or create segmented plates (reminiscent toddler plates; **Figure 2**). The image in the bottom right is a piece of strategic design by Fajar Kurnia, Jeremy Chia and

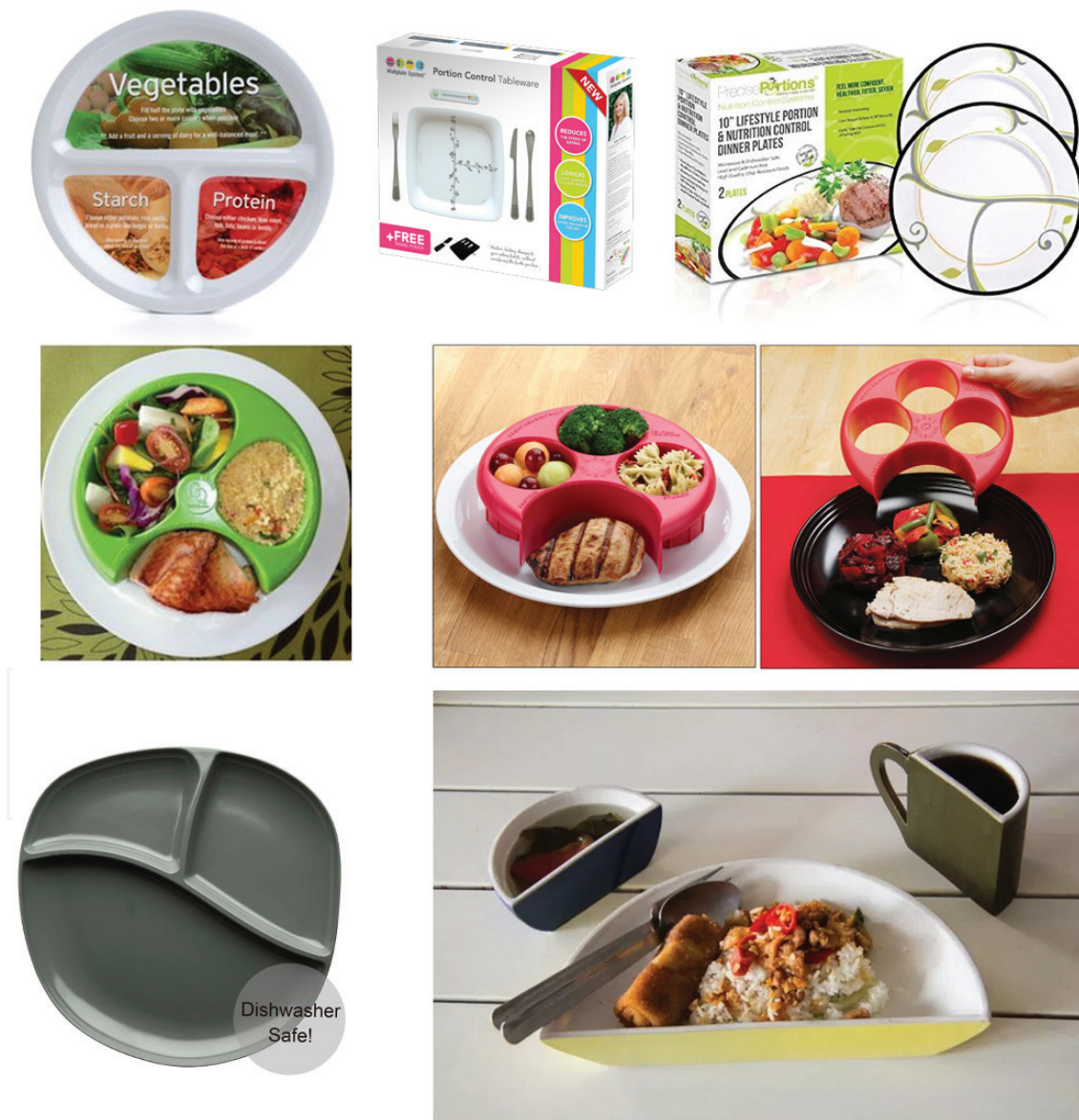


Figure 2. Current portion control plates. Photo or Design Credit to: (from top left to bottom right) Health.com, Precise Portions: Nutrition control system, Calorie Queens: 3D dinner Divider, Meal Measure: portion control plate, Zak's Moso: bamboo divided dinner plate, Halved by Fajar Kurnia, Jeremy Chia and Jo Djauhari.

Jo Djauhari which has a lovely playful approach but still does not address the psychological aspects of portion control. Problematically, these approaches remind people they are being limited in what they are eating; which makes it harder for people to sustain their portion control. Rather than this explicit attention-enhancing approach, Wansink argued [14] that we should seek.

“...small changes in the eating environment (such as package downsizing, smaller dinnerware and reduced visibility and convenience) that can be easily implemented ... to help solve mindless overeating.”

and claimed

“It is easier to change our food environment than to change our mind.”

The team created a range of concepts, each with the aim of making the food on the plate or bowl seem larger (**Figure 3**). The idea of a humped base to make the pile of food seem larger was developed further into the MindFull bowl and plate. The MindFull solution addresses the design implications from the literature review (**Figure 4**). It uses heavy materials to create a false sense of density, and the design is wide to activate the haptic cues for size. The round curved form and asymmetry makes it harder to judge the volume accurately. The shape of the bowl forces users to hold the bowl flat on their hand or stretch their grasp, which enhances the sensory cues for size. The lack of a raised rim obliges the user to scoop their food slowly to stop the food from spilling. Similarly, the angles of the bowl's interior make it easy to chase food around in circles; slowing consumption. The surface finish is smooth rather than textured, to add to the impression of size. Finally, the rounded forms have association with a baby schema, hopefully, activating the attention bias to avoiding overeating due to distraction (**Figure 5**).



Figure 3. Development. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

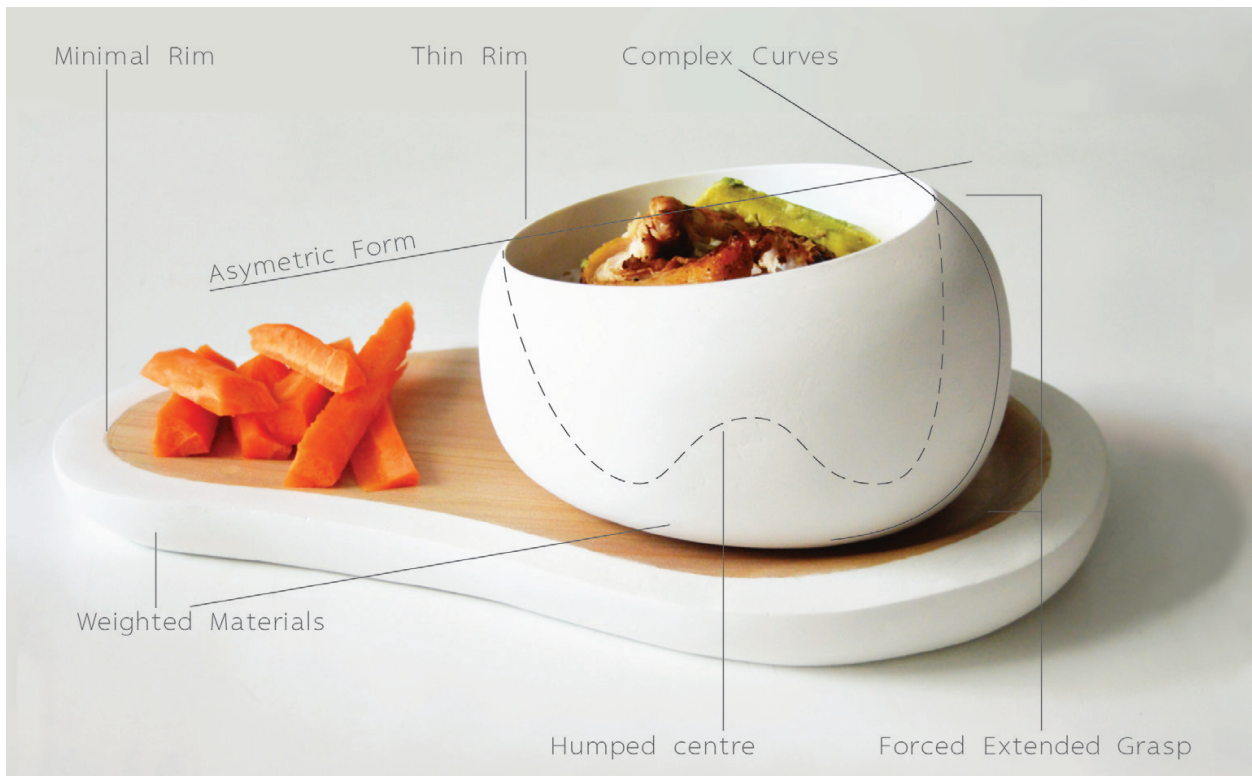


Figure 4. Design solutions to manipulate sensory perception. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.



Figure 5. MindFull details. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

3. Testing

To see if there were indications that any of our assumptions might work, we put the design through two preliminary user-testing sessions.

3.1. Test 1

The first test was a between-subjects test comparing the portion sizes of self-served portions of rice in the MindFull bowl and plate with portion sizes in a standard bowl and plate.

3.1.1. Participants

A total of 44 undergraduate students between 18 and 21 years were approached at the University between 10 and 11:30 am to volunteer for 2 minutes in a food experiment. They were asked their current hunger levels: hungry, content or not hungry. Each group had an even split of gender and were matched on hunger levels.

3.1.2. Apparatus

The testing environment consisted of a partitioned-off area within a studio environment (**Figure 6**). A video camera was set up to record the process. One table held a large bowl of rice with a serving spoon. The MindFull bowl and plate and a standard bowl and plate were placed out of sight behind a box. On the second table, a sheet of plastic was laid out with a camera on a tripod above to photograph the portion sizes.



Figure 6. Photograph during test one. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

3.1.3. Method

Participants were asked their hunger level (“hungry”, “content” or “not hungry”), handed a plate or bowl from either the standard set or the MindFull set and asked to serve themselves what they considered their normal portion of rice. Once they had served themselves, the rice was tipped out and photographed from above with the chosen hunger level label and a small note of what plate or bowl it came from. The participant was thanked and given a small sweet. This process was repeated for each participant.

3.1.4. Results

The photographs of the rice portions were collated and processed by dish type to create **Figure 7**. The number of spoonfuls each participant served was recorded and independent sample t-tests were conducted to compare. There was a significant difference between the amount of food served in the MindFull bowl (M = 2.5, SD = 1.11) and the standard bowl (M = 4.8, SD = 1.09) conditions; $t [15] = 3.23, p = 0.003$. However, there was no significant difference between the amount of food served in the MindFull plate (M = 2.62, SD = 1.09) and the standard plate (M = 3.5, SD = 1.65) conditions; $t [12]=1.60, p = 0.12$.

3.1.5. Limitations

These results indicate aspects of the MindFull bowl may be effective; however, there are many limitations to study. It would have been much better to conduct within-subject experiments or to have matched the participants in each group by size and BMI. More accurate measurements of the servings also would have given more accurate results.

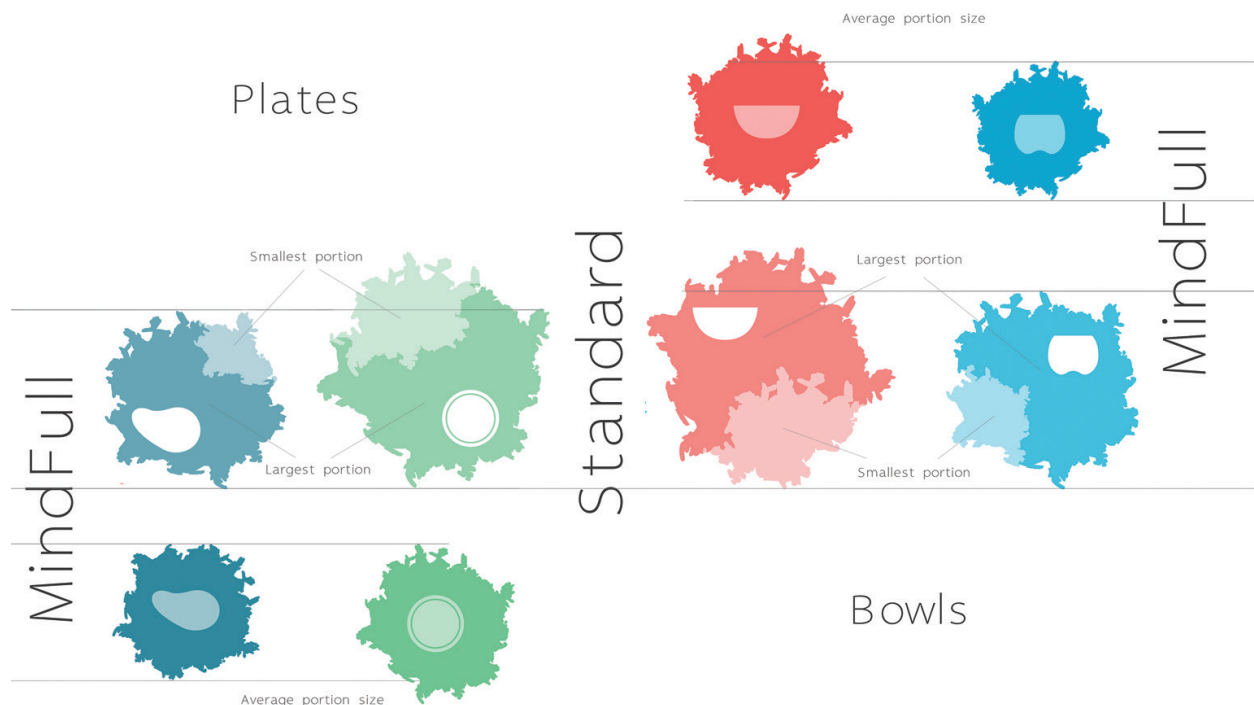


Figure 7. Infographic showing the largest, smallest and average portion sizes served in each dish—made from photographs of the rice portions.

3.2. Test two

This study took a qualitative approach. It used a within-subjects design to compare people's experiences with the MindFull dishes versus standard dishes.

3.2.1. Participants

Participants consisted of two males and two females all aged 19 years, who were not aware of the details of the project. The four participants were told they would eat two lunches on separate days and be asked about their satisfaction levels. They were asked to choose 2 days where they would wake up at the same time and to have similar breakfasts each of the days. They were also asked about any food allergies and preferences. In return for their time, they received two free lunches, which were eaten in the course of the testing.

3.2.2. Apparatus

The bowl and plate, designed by the MindFull team, were used during the first test, and a standard white bowl and plate set were used in the second. A questionnaire asking about food consumption that morning, their satiety and satisfaction levels and their thoughts on the experience was given at the end of the testing process. A video camera was used in order to film the participant during the experiment. A knife, fork, table and chair were provided in a portioned-off section of a studio space. The meal provided was a fresh vegetable pasta salad with sliced cucumber and carrot offering a variety of flavours to reduce the fullness being reached due to flavour fatigue [33] (**Figure 8**).

3.2.3. Method

Participants were asked what time they had woken up, what they had for breakfast and what time they had eaten it. They were also asked to rate their hunger levels on a scale of



Figure 8. Food served in test two. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

0–10: 0 = full, 4 = content, 8 = hungry and would eat if food was available, 10 = extremely hungry and would go out of the way to find food. The food was laid out on a table as shown in **Figure 8**, and they were invited to start eating. Participants were engaged in conversation while eating and were encouraged to verbalise how they felt during the process, employing aspects of the ‘think out loud’ method [34] (**Figure 9**). The first day, they ate from the MindFull bowl and plate. The second day, they use the standard set. The tests were 2 days apart. Once the participant finished the meal, they were asked to rate their fullness levels from 0 to 10, 0 = hungry, 10 = over full, 7 = comfortably full, their satisfaction levels, 0 = unsatisfied, 10 = very satisfied, 5 = neutral, and to add any comment about their experience. After completing the second test, they took part in a semi-structured interview asking their impressions of the design, how they would compare the two experiences?, would they like to have it in their home?, could they see themselves purchasing the design? and any frustrations or joys they experienced while eating.

3.2.4. Results

There was no difference in the satisfaction or fullness levels between MindFull and the standard tableware.

A deductive thematic analysis was done of the conversations, questionnaire comments and semi-structured interviews looking for comments related to the perception-based design features and opinions on the design. The videos of the sessions were also analysed for behaviour and body language.



Figure 9. Photographs taken during test two. Photo credit to Jessica Noone, Daphnee Belleil, Isla Davies and Lucy McMaster.

Generally people found the MindFull set more exciting and special.

"Oh it's [Standard set] not as exciting this time"

"It is interesting how a meal is displayed makes such a different to how much you want it"

"I really like the other plate [MindFull]... I would just want to have it displayed on my bench..., I particularly like the wood"

"The other one is too special for every day, I only get it out for special things."

"Funny, the food seemed more interesting in the other plate [MindFull]"

There were only a few comments on the portion sizes, two participants thought the MindFull set had more food, one could not tell and the last thought it had less.

"Is it more food this time? It feels like more" [Standard set]

"Do I have to finish all of it?" [MindFull]

"The bowl was quite fat looking I thought it was going to be too much" [MindFull]

"Is it the same portion sizes?"

In their written comments about MindFull they said

"I thought the bowl was super full and I wouldn't be able to finish, but it was actually a good serving size."

"It was nice, filled me up. Took my time and enjoyed it."

Two participants mentioned how the different tableware changed what you could see of the food.

"It was sooo round and cute, the food was more 'in' the bowl so you couldn't see how much there was."

"the food is more on top of this bowl, you know, you can see it."

Interestingly, these were the two participants who had strongest opposing perceptions of portion size. The one who said you could not see how much food thought MindFull had a big portion size and the one who noted you could see the food in the standard set thought MindFull had a smaller portion size. This could indicate one read the portion size only as the food he could see, while the other added the bowl into the equation.

When looking at the behaviour, participants very seldom touched the MindFull set, but they often repositioned and held the edge of the standard set. They also tended to take more time getting the food onto the fork in the MindFull condition, and the amount of food on each forkful was generally less. This could be because the design features were effective, or it may be because they were more concerned about damaging the design. Three of the four participants commented they had to be careful not to spill the food when eating with MindFull.

"There is a knack to eating with that one, but for me I don't mind 'cause it feels so much nicer"

Participants also seemed more relaxed with the standard set; however, this may have been due to having completed the test before. A larger sample size controlled for order effects

would have been beneficial to address these issues. When commenting on the design two participants, expressed storage could be an issue as MindFull does not stack tightly. Three of them mentioned if they had the set they would want it on display. All of these findings only offer initial insights due to the small sample size.

4. Discussion

People use a variety of heuristics to estimate size from a range of visual and haptic perceptions. These heuristics are not accurate in all circumstances and can lead to very inaccurate estimates at times. The MindFull bowl and plate were designed with a number of features that exploited the limitations of these heuristics to present an illusion of larger portion sizes in order to assist people to unconsciously reduce and control their eating.

The experiments reported in this paper give a preliminary indication that the design may be successful. In particular, the MindFull bowl merits further investigation, as it significantly alters the perceived portion sizes in comparison to a normal bowl. However, more rigorous testing in a greater range of situations and with larger sample sizes would be needed to confidently validate the design.

The MindFull plate did not appear to be as effective. We postulate this may be because the mound on the MindFull plate is visually prominent, resulting in users being more aware of it and not deceived by the illusory perceptual consequences. The MindFull bowl, on the other hand, has a less visually prominent mound, making it much harder for the user to be aware of the perceptual manipulation. The food also hid the shape of the internal walls making it difficult to judge the wall thickness and know how much was food and how much was bowl.

Furthermore, the shape of the MindFull bowl meant less of the food portion was visible than on the MindFull plate, so the container itself had a more dominant effect on the perception. The bowl also incorporated more identified design implications than the plate. It had a more unconventional and complex shape, which may have directly defeated many of the standard heuristics for estimating size. Unlike the plate, the bowl gave a haptic sensation of a larger container, as it was unwieldy when held in one hand, adding to the illusion of a big portion size. The difference between the weight of the MindFull bowl and the standard bowl was much higher than the difference in weight between the MindFull plate and the standard plate. This could mean the illusion of the weight-to-size ratio was stronger in the bowl making it more successful. Since the weight-to-size heuristic is particularly robust against cognitive awareness, we suggest this factor was particularly important in preventing people from using slower (but more accurate) thinking processes to overcome the deceptive sensory signals. To determine which of the strategies were most effective, the variables would need to be isolated in further testing.

The way participants served their own food in the first study was a significant limitation because they could feel the weight of the food in the serving spoon as well as count the number of spoonfuls. This process probably reduced the effectiveness of the sensory manipulations by the bowl or the plate. To truly test the effects of the design features, future experiments should

modify the way the food is served to remove this limitation. However, serving food would happen in regular use of the tableware, which suggests a further design opportunity to create a weighted and/or complex shaped serving spoon that employs similar sensory illusions. Additionally, after eating, the shape of the bowl is made visible, so the perceptual illusions are more obvious, possibly inducing the user to reassess their expectations. This may have been a factor in one of the comments in the second study: "I thought the bowl was super full, and I wouldn't be able to finish, but it was actually a good serving size". It is unclear what effect this post-eating change in expectations would have on satiety, but it could be a severe design limitation.

The results of the second study were not as rigorous but did give indications for design improvements. Generally, the responses and satiety levels did not contradict the effectiveness of the MindFull approach. A big flaw in this study was not having participants pick up and handle the tableware, since many of the features targeted haptic feedback. A study with more participants and a setup where tableware is handled would be beneficial.

Overall, we conclude it could still be worth exploring MindFull and additions to the MindFull range of items, such as serving spoons, cutlery, glasses and serving bowls. The MindFull range of tableware is but one design approach to helping people control their eating; yet it demonstrates the potential of good design in this area. Due to the enormous cost of obesity to our society, investment into design which could help us eat less is of immense worth.

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