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Short communication

Dining in the dark: The importance of visual cues for food consumption and satiety

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ABSTRACT

How important are visual cues for determining satiation? To find out, 64 participants were served lunch in a "dark" restaurant where they ate in complete darkness. Half the participants unknowingly received considerably larger "super-size" portions which subsequently led them to eat 36% more food. Despite this difference, participants' appetite for dessert and their subjective satiety were largely unaffected by how much they had consumed. Consistent with expectations, participants were also less accurate in estimating their actual consumption quantity than a control group who ate the same meal in the light.

Nikola Tesla, the eccentric inventor, worried about eating anything of which he could not visually judge the size before he consumed it (Hunt & Draper, 1964). As Tesla was also concerned about his weight, his peculiar behavior could have been connected to a fear of overeating when lacking appropriate visual input. But how important are visual cues relative to other sources of information for controlling our food consumption and influencing when to stop eating? People often appear to rely on visual cues to terminate consumption (Wansink, Painter, and North, 2005; Fedoroff, Polivy, & Herman, 1997; Schachter, 1968): in the simplest case, people may stop eating once they empty their plate, which can lead to increased consumption with larger dishes and portion sizes (Diliberti, Bordi, Conklin, Roe, & Rolls, 2004; Levitsky & Youn, 2004). When eating in a group, people may also adjust their consumption to what they see others eating, presumably because this sets an implicit consumption norm (Herman, Roth, & Polivy, 2003). On the other hand, physiological research has identified a number of internal post-ingestive processes that trigger the inhibition of appetite. These processes may rely on cues including saliva secretion, gastric acid secretion, insulin release, and several neuropeptides (Schwartz, Woods, Porte, Seeley, & Baskin, 2000; Speakman, Stubbs, & Mercer, 2002). Thus, the question emerges how external visual cues and internal physiological ones interact to influence consumption and satiety.

To the extent that food intake is often governed more by external than internal cues (Wansink, Payne, & Chandon, 2007), subjective feelings of satiety may depend little on the actual amount of food in the stomach. In line with this, Rolls, Morris, and Roe (2002) found that larger portion sizes led to more consumption among participants but did not affect their subsequent ratings of hunger and fullness. Other experiments indicated that participants who ate a meal while blindfolded consumed significantly less food but felt just as satiated as a sighted control group (Barkeling, Linné, Melin, & Rooth, 2003; Linné, Barkeling, Rössner, & Rooth, 2002). Likewise, Wansink et al. (2005) showed that manipulating visual cues of how much is eaten influences further intake, suggesting that "people use their eyes to count calories and not their stomachs" (p. 98). Together, these findings suggest that—at least in the short run—internal cues of satiety might provide weaker (and possibly less accurate) feedback than visual cues for when to stop eating. As perhaps felt by Tesla, this could pose a problem of portion control in cases where it is difficult to visually estimate the available amounts, for example when watching television, sitting in front of a computer screen, or when attention is directed toward other stimuli (Blundell et al., 2005; Jeffery et al., 2007).

To find out whether people are more or less accurate in determining consumption and satiation using visual or internal cues, we need to separate the influence of both cue types. One way to experimentally control for visual cues of how much oneself and others are eating is by serving food in complete darkness. Although in the dark the amount of food provided on the plate could still be estimated by touch or by counting bites, normal-sighted people should be unaccustomed to these methods. As a consequence,

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internal satiety cues may increase in importance. The reliability of these internal cues will then influence how well people eating in the dark can estimate the amount of food they consume as compared to people eating under normal light conditions. This, in turn, should also affect people's subsequent feelings of satiety.

Thus, we hypothesize that people's ability to estimate the actual amount of food they consume will be impaired if they are deprived of visual cues by eating in the dark. We further hypothesize that people's satiety after the meal in the dark will be less contingent on the actual amount of food they previously ate, compared to people eating in the light.

Method

To test these hypotheses, we conducted an experiment in which we invited participants for lunch in a so-called "dark" restaurant in downtown Berlin, Germany. This restaurant consisted of two parts, an entrance and bar area in the light and a dining area in the back where no light was visible. In the dining area, patrons were served in complete darkness by sight-impaired waiters and waitresses who were capable of maneuvering in the dark. Participants ate two main courses sequentially in the dark dining area. Following this, participants were offered a dessert in the light that they could serve themselves. Thus, the setting was the same as a normal restaurant in all respects except for the lack of any light in the dining area. To experimentally manipulate the amount of available food, we varied the portion sizes of the two main courses between participants such that one group received regular-size portions while the other group received super-size portions. The main dependent variables were participants' accuracy in estimating the amount of food they had consumed and their satiety after the meal. As a control condition, another group of participants on a different day ate the same food in a similar but well-lit room at the same restaurant.

Experimental procedure

The experiment in the dark took place around noon on two consecutive weekdays with groups of 32 participants per day. The control condition in the light took place a few weeks later, on one weekday also around noon. Participants in both conditions were invited for a study that involved a free lunch; those in the experimental condition were told beforehand that the lunch would be served in complete darkness. No further information about the purpose of the study was given. At the time of the invitation, participants were also asked about their weight and height. On the day of the experiment, participants were welcomed at the entrance area of the restaurant. Prior to the lunch, only vague information was given about the nature of the food and nothing was mentioned about the size of the portions. Participants were asked to talk about anything over lunch except the food itself, and to take off their watches and cell phones to eliminate potential light sources. Then they were guided to their tables by the restaurant staff. In the experimental dark condition, the tables were in the lightless dining room. In the lighted control condition, the tables were set up in the entrance area of the restaurant. Tables were shared by 8 participants.

The lunch consisted of two main courses prepared by the professional restaurant chefs and served by the restaurant staff on regular plates. The first course was vegetable risotto, followed by the second course of goulash with noodles. Together with these two courses the restaurant served each participant 5 pieces of white bread and a glass of plain water (refilled upon request). Plates were removed by the restaurant staff after all participants at a table had finished eating (which was determined by asking them whether they were done). To measure the exact amount of food that was served to and consumed by each participant, we weighed each plate before it left the kitchen and after it was cleared from the table.

In both conditions, the dessert was served in the entrance area of the restaurant in the light on separate tables. In the experimental condition, participants were guided out of the dark area by the restaurant staff once everyone at their table had finished their meal; in the lighted condition, participants were moved to different tables. The dessert consisted of large plates with fruit pieces (tangerine, apple, and grape with cheese) impaled on colored toothpicks, from which participants could serve themselves. Each participant had a plate to drop their empty toothpicks on, so that we could assess the individual amount of dessert consumption by counting the number of toothpicks on each plate. Following this dessert, participants filled out a questionnaire and were then debriefed, compensated with a 10 EUR show-up fee, and thanked for their time.

In the experimental condition, every other participant at each table received regular-size portions with an average amount of 172 g of risotto (SD = 18 g) and 309 g of goulash (SD = 38 g). The rest of the participants in the super-size portion group on the first day received approximately twice as much risotto (M = 338 g, SD = 17 g) while the second main course dish was kept the same size (M = 305 g, SD = 31 g). To test whether the distribution of extra food across the first and the second dish made a difference, on the second day the super-size group received larger portions of both main dishes, on average 270 g risotto (SD = 27 g) and 494 g goulash (SD = 56 g) (the two main courses were of comparable energy density). We found no consistent differences in behavioral measures between the super-size portions on the two days; therefore, our subsequent analyses are based on the total amount of food across both main courses. For participants in the combined super-size group this came out to an average of 706 g (SD = 77 g) of food served, which is 225 g (47%) more than those in the regular-size group (M = 481 g, SD = 42 g).

In the control condition in the light, the average regular serving sizes were 451 g (SD = 69 g) and the super-size servings were 636 g (SD = 75 g). The resulting difference of 186 g (29%) was slightly smaller than in the dark, so if anything, differences in portion sizes in the light were more subtle and thus harder to detect visually.

The questionnaire at the end of the experiment asked each participant to write down an estimate of the total weight (in grams) and the number of calories that they had consumed for both main dishes. As a behavioral measure of participant's satiety after the two main courses, we counted the number of fruit sticks they had served themselves for dessert. As a subjective satiety measure, participants rated their current hunger ("how much hunger do you have right now") on a scale from 1 (none) to 5 (very much). They also rated their feelings of hunger ("I'm feeling hungry") and of having overeaten ("I have the feeling that I ate too much"), on a scale from 1 (not at all) to 7 (very much). Finally, a number of control variables were assessed by entering them in the data analysis as covariates in an ANCOVA design: On a 7-point scale (1= Strongly Disagree; 7 = Strongly Agree), participants rated their food preferences ("I liked the taste of the food"), distraction ("I paid attention to the taste of the food", "I paid attention to how much I ate"), and difficulty while eating ("It was difficult to eat the food").

Participants

Participants were recruited from the subject pool of the Max Planck Institute for Human Development in Berlin, comprising university students and people from local communities. Mean age was 24 years (SD = 3.3), and mean body-mass index (BMI) was 22.9 kg/m^2 (SD = 3.0). Out of all 96 participants, 51 were female and 74 were students. No participant was vegetarian or currently on a diet, and no one had ever eaten at a "dark" restaurant before. Participants in the super-size group and in the regular-size group were matched by gender, age, student status, and BMI. Likewise, participants in the control condition were matched to those in the experimental condition by age, BMI, and gender. For two participants, no accurate consumption measures could be obtained, reducing the number of valid cases to 63 in the experimental condition and 31 in the control condition.

Results

The assessed control variables did not differ significantly ($\alpha < 0.05$) between the groups with regular and with super-size portions, but did differ between light and dark conditions. Participants eating in the dark gave similar taste ratings compared to those in the light but found eating more difficult ($M = 2.48$ vs. 1.44, $t(94) = 3.96$, $p < 0.001$), paid more attention to the taste of the food ($M = 5.24$ vs. 3.91, $t(93) = 4.22$, $p < 0.001$), and paid less attention to how much they ate ($M = 2.75$ vs. 3.53, $t(93) = -2.21$, $p = 0.030$). Across all participants, taste ratings were positively correlated with estimated consumption ($r = 0.30$, $p = 0.004$). The other three control variables though showed no statistically significant correlations with the dependent measures of amount of food consumed or estimated.

Consistent with prior findings on restaurant portions (Rolls et al., 2002), regardless of the size of portion they were served, participants tended to eat the majority of the food on their plate. As a result, the amount they ate varied proportionately with how much they were served. When eating in the dark, participants with regular portions on average ate 462 g ($SD = 54$ g), which was 96% of the amount served. Those with super-size portions on average ate 627 g ($SD = 106$ g), 89% of the amount served. The difference of 165 g (36%) was statistically significant in the ANCOVA test, $F(5,55) = 53.3$, $p < 0.001$. In the lighted control condition, amounts eaten were 432 g or 96% ($SD = 73$ g) and 525 g or 83% ($SD = 109$ g) respectively–a difference of 93 g (22%), $F(5,22) = 3.1$, $p = 0.091$.

On average, participants with regular portions in the dark slightly overestimated the amount of food they had actually eaten ($M = 496$ g, $SD = 147$ g) while those with super-size portions slightly underestimated it ($M = 576$ g, $SD = 224$ g). Thus, even though participants in the dark with super-size portions actually consumed 36% more food than those with regular portions, their estimate is only 16% higher, $F(5,55) = 3.6$, $p = 0.063$. However, the fact that estimates for super-size portions were still slightly higher than for regular portions suggests that even without visual cues, people are not completely lost but can still derive some, albeit systematically distorted, estimates of how much they have eaten based on other cues. Comparable results were obtained for the estimation of calories consumed: people in the dark with super-size portions estimated eating only 11% more calories than those with regular portions, $F(5,56) = 1.9$, $p = 0.179$.

In the control condition in the light, participants' mean consumption estimates were 416 g ($SD = 143$ g) for regular portions and 504 g ($SD = 121$ g) for super-size—a difference of 21%. The actual difference in amount consumed was 22%, indicating that participants eating in the light were better calibrated than those eating in the dark. (The estimation of calories for super-size portions was 30% higher than for regular portions.)

Summed across both portion sizes, the absolute difference between estimated consumption and actual consumption in the dark was 160 g ($SD = 114$ g) as compared to 104 g ($SD = 87$ g) in the light, $F(5,82) = 4.8$, $p = 0.031$, further indicating that the estimation was significantly worse when visual cues were not available (Fig. 1).

In the dark experimental condition, those served regular portions on average ate 8 fruit sticks ($SD = 4.0$) for dessert (in the light) while those with super-size portions ate 7 ($SD = 3.5$), $F(5,52) = 0.6$, $p = 0.432$, indicating that the amount of dessert consumed was independent of main-dish portion size. In contrast, participants in the light who ate regular portions took 12 fruit sticks ($SD = 5.4$) compared to only 8 for those with super-size portions ($SD = 3.8$), $F(5,19) = 4.0$, $p = 0.061$, so that dessert consumption was contingent on main-dish portion size for them (Fig. 1).

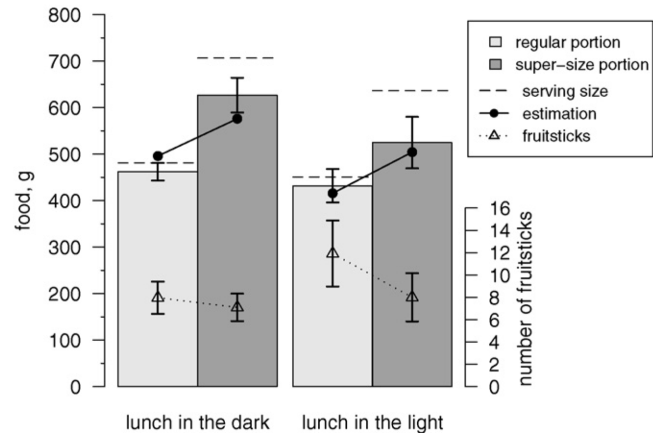

Fig. 1. Mean amount of food served during the main courses (dashed lines), relative to the amount consumed (bars), the estimated consumption (black dots), and the number of consumed fruit sticks for dessert (triangles). Error bars indicate 95% confidence intervals of the mean amount consumed.

Despite the differences in consumption of both main dishes and dessert, participants' subjective satiety at the end of the experiment was similar across the experimental conditions. To compare satiety, the three self-report measures were re-scaled to a common range and then averaged into a single score from 0 (not satiated) to 1 (fully satiated). This satiety score was rather high across all participants ($M = 0.84$; $SD = 0.13$), and when averaged across the dark and light condition there was no difference between people who ate the regular versus the super-size portions, $F(5,88) = 1.9$, $p = 0.139$.

Discussion

Contrary to the saying that someone's "eyes were bigger than their stomach", we found that people guided by visceral cues while eating the dark actually ate more of large portions than did people whose eyes guided their eating in the light. In both conditions, large differences in the amount of food served led to large differences in the amount of food eaten, confirming past research showing that consumption is contingent on portion size. But this contingency was stronger in the dark, where visual cues were not available and internal satiety cues gained prominence. As a consequence, people with super-size portions in the dark consumed more food compared to those in the light, where visual cues helped people to regulate their intake more and stop eating sooner. With regard to the estimation of food consumption, participants in the dark were significantly less accurate than those in the light who saw the food on their plates. Together, these results support our first hypothesis that people's ability to estimate their consumption is lessened in the absence of visual cues.

The amount of dessert that participants served themselves after the meal in the dark was largely independent of the amount of food they had previously consumed, suggesting that they felt equally hungry after the two portion sizes. In contrast to this, participants in the control condition in the light who ate super-size portions served themselves less dessert than those who ate regular portions. This supports our second hypothesis that satiety is more contingent on visual than internal cues.

At the same time, the self-report measure of satiety was less conclusive. Participants in the dark condition felt equally satiated at the end of the experiment independent of their portion size, mirroring their equal consumption of dessert. However, this also held true for those who ate in the light. To some extent, this could be due to the fact that the differences in the actual amount of consumption were less extreme in the light and that participants further compensated for that difference by eating less dessert if they had eaten a larger main-dish portion, evening out their final reported satiety.

Limitations and future research

The experiment took place in a real restaurant setting with the goal of achieving high external validity. Besides its virtues, this approach though only allows assessing but not controlling some of the potentially confounding variables. For example, participants eating in the dark reported that they paid more attention to the taste of the food and less attention to how much they ate and had more difficulty eating. While these variables did not correlate with the dependent variables, they indicate that eating in the dark not only removed visual cues but also somewhat changed the eating experience in other respects.

Eating in the dark also removed the visual cue of how much others at their table ate and thus inhibited possible consumption norms. In contrast to this, in the light it might have been more socially acceptable for those with relatively smaller main-dish portions to consume more dessert. To partly control for this influence, we made it more difficult to reconstruct how much others had been eating by moving participants from their main-dish serving tables to different tables with other people for dessert. Likewise, it is possible that people in the dark ate more from the super-size portions because the lack of social control allowed them to dis-inhibit their behavior. However, while this could explain why participants *ate* more from the super-size portion in the dark, it does not explain why they subsequently underestimated the amount they had consumed.

On average, eating in the dark took 10–15 min longer than eating in the light. To the degree that internal satiety cues are time-delayed, the meal extension in the dark should have increased the reliability of internal cues and thus increased estimation accuracy. On the other hand, a longer time period can also increase memory load which might have added noise to people's later estimates of their consumption (Higgs, 2008). This difference in meal duration could also account for the distinction between our results and those of Linné et al. (2002), who found that sighted people ate less without visual cues, but also ate for less time. However, their experiment also differed from ours in a number of other ways that could have changed consumption: portion size was held constant, people ate a single meal on their own, and they were wearing a blindfold which might have been unpleasant.

Finally, our results might hold less for people who are visually impaired or accustomed to eating in the dark, because these people might have learned to use other external cues (such as counting bites) to estimate their consumption.

Conclusion

The results of our experiment indicate that non-visual cues do not provide as accurate input as visual cues for estimating food quantities and satiety and thus for stopping consumption. Without easy access to visual cues, for example when watching TV in dim light, people may readily misestimate what they are eating. Our findings support the powerful effects on consumption of manipulating visual food cues reported in previous research (Wansink, 2004). They further indicate that the low sensitivity to visceral feedback found among obese people (Schachter, 1968; Stice, Spoor, Bohon, & Small, 2008) may also apply to normal-weight people like those who participated in our experiment. The visual (beyond just the visceral) food environment exerts an important influence that should not be overlooked: in this respect Tesla was right to avoid eating portions that cannot be visually estimated.

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