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Meal Size, Not Body Size, Explains Errors in Estimating the Calorie Content of Meals

Brian Wansink, PhD, and Pierre Chandon, PhD

Background: Although most people underestimate the calories they consume during a meal or during the day, calorie underestimation is especially extreme among overweight persons. The reason for this systematic bias is unknown.

Objective: To investigate whether the association between calorie underestimation and body mass reflects a tendency for all persons to underestimate calories as the size of a meal increases.

Design: Overweight and normal-weight adults estimated the number of calories of a fast-food meal they had ordered and eaten (study 1) or of 15 fast-food meals that were chosen by the experimenter (study 2) in a randomized, controlled trial. Their estimations were compared with the actual number of calories of the meals.

Setting: Study 1 was a field study conducted in fast-food restaurants in 3 medium-sized midwestern U.S. cities. Study 2 was conducted in a laboratory at a major U.S. research university.

Participants: Study 1 involved 105 lunchtime diners (average body mass index [BMI], 24.2 kg/m^2 [range, 17.2 to 33.5 kg/m^2]). Study 2 involved 40 undergraduate students (average BMI, 23.2 kg/m^2 [range, 16.1 to 32.3 kg/m^2]).

Measurements: Participants were asked to estimate the number of calories in a fast-food meal they had ordered and eaten (study 1) or in 15 sizes of the same fast-food meal (study 2). The actual number of calories in the meals in the field study was obtained by unobtrusively recording the food that was ordered (identified from the wrappings and containers). Weight and height were self-reported.

Results: Although participants strongly underestimated the number of calories in larger meals (by −38.0% in study 1 and by −22.6% in study 2), they almost perfectly estimated the number of calories in smaller meals (by −2.9% in study 1 and by 3.0% in study 2). After the authors controlled for body weight–related differences in meal size, the calorie estimations of normal-weight and overweight participants were identical in both studies.

Limitations: These studies examined fast-food meals. Weight and height were self-reported. There were too few observations to distinguish between obese (BMI ≥30 kg/m^2) and overweight (BMI >25 kg/m^2 but <30 kg/m^2) participants.

Conclusions: Greater underestimation of calories by overweight persons is a consequence of their tendency to consume larger meals. Calorie underestimation is related to meal size, not body size.

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For author affiliations, see end of text.

From an energy intake perspective, it has been argued that underestimation of the increasing sizes of restaurant and home-cooked meals is contributing to the rising obesity rates in the United States (1–4). Although nearly all persons underestimate their calorie intake, considerable evidence indicates that the bias is much worse for those who are overweight (5–8). Clinicians and researchers have proposed a wide range of possible reasons, leaving recent reviews to conclude that the cause of this bias is "unclear" (9) and, more fundamentally, that "we still need to understand why people misreport food intake" (6).

In clinical treatments of obese persons, it is often assumed that they intentionally underestimate food intake to improve their self-esteem (self-deception) or the way they are viewed by others (self-presentation) (10). We contend that biases in calorie estimation have a perceptual—not motivational—origin and that meal size, not body size, explains the calorie underestimation of meals. Building on the empirical law of sensations (11, 12), we examine whether subjective estimations of calories, like other perceptual estimations, increase at a slower rate than the actual increase in meal size.

We tested 3 hypotheses: 1) Every person's estimation of calories follows a predictable pattern of diminishing sensitivity to increases in meal sizes; 2) once meal size is controlled for, there are no differences in the estimation biases of overweight and normal-weight persons; and 3) the differences between overweight and normal-weight persons are a result of overweight persons choosing larger meals.

Methods

In study 1, trained interviewers asked overweight and normal-weight persons who had finished eating at fast-food restaurants to estimate the number of calories in their meals and to provide their heights and weights. At the same time, the interviewers unobtrusively recorded the type and size of the food eaten. Although externally valid, study 1 cannot rule out the possibility of self-selection biases (because some people declined to participate in the

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study) and motivational biases (because some people may have been more motivated by fear of embarrassment than by a desire for accuracy). Another limitation is that the meals varied in both size and type of foods.

To overcome these limitations, a second study was conducted in a laboratory ensuring high levels of motivation and no attrition. In study 2, we asked a different group of overweight and normal-weight participants to estimate the calories in 15 experimenter-selected fast-food meals differing only in portion sizes. Whereas study 1 examined postintake, between-participant calorie estimations, study 2 examined preintake, within-participant calorie estimations. The 2 studies combined provide external and internal validity in this investigation.

Study 1 Design: Postintake Calorie Estimation of Self-Selected Fast-Food Meals

Study 1 was conducted in fast-food restaurants on 9 weekdays in 3 medium-sized midwestern U.S. cities during the noon hour. The targeted restaurants were nationwide hamburger and sandwich chains and were located within 150 feet of each other. Trained interviewers approached every fourth person who was finishing a meal and asked whether he or she would answer some brief questions for a survey. The institutional review board at the University of Illinois approved the study.

Persons who agreed to participate in the survey were then asked whether they were 18 years of age or older and whether they ate at this particular fast-food restaurant at least once per month. If participants answered yes to these 2 questions, they were asked to estimate the total number of calories contained in their entire meal, not the number of calories that were consumed. Participants were asked to

Current Author Addresses: Dr. Wansink: 110 Warren Hall, Cornell University, Ithaca, NY 14853-7801.
Dr. Chandon: INSEAD, Boulevard de Constance, 77300 Fontainebleau, France.

Author Contributions: Conception and design: B. Wansink, P. Chandon.
Analysis and interpretation of the data: B. Wansink, P. Chandon.
Drafting of the article: B. Wansink, P. Chandon.
Critical revision of the article for important intellectual content: B. Wansink, P. Chandon.
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Administrative, technical, or logistic support: B. Wansink, P. Chandon.

Appendix

To examine the relationship between estimated (E) and actual (A) number of calories, we linearized the power model through a log–log transformation: $(\ln(E) = \ln(a) + n \times \ln(A))$. For study 1, in which each participant made 1 estimate, we estimated the linearized model through ordinary least squares using PROC UNIANOVA in SPSS, version 13.0 (SPSS, Inc., Chicago, Illinois). For study 2, in which each participant made 15 estimates, we accounted for correlated errors within participants by using PROC MIXED in SPSS, version 13.0 (SPSS, Inc., Chicago, Illinois), assuming a compound symmetry covariance structure and using restricted maximum likelihood estimation. In study 1, the point estimate and CI of the intercept (ln(a)) and power exponent (n) were 2.517 (95% CI, 1.390 to 3.644) and 0.564 (CI, 0.378 to 0.715), respectively. In study 2, the point estimate and 95% CI of the intercept (ln(a)) and power exponent (n) were 2.383 (CI, 2.153 to 2.613) and 0.627 (CI, 0.597 to 0.657), respectively. In both studies, the power exponent was statistically below 1, indicating that estimations are inelastic. The predicted intersection point at which estimated and actual calories are identical $(A \times = a^{1/(n-1)})$ is 323 calories in study 1 and 591 calories in study 2.

To further test that calorie estimations follow an inelastic power function of actual calories, we compared the fit of the power model with the fit of a linear model $(E = a' + n' \times A)$. The power model fit the data better than the linear model in study 1 ($R^2 = 0.30$, $t = 6.6$, $P < 0.001$ for the power model and $R^2 = 0.25$, $t = 5.9$, $P < 0.001$ for the linear model). These results were replicated in study 2 ($R^2 = 0.34$, $t = 17.4$, $P < 0.001$ for the power model and $R^2 = 0.31$, $t = 16.2$, $P < 0.001$ for the linear model. For comparison purposes, both models were estimated through ordinary least squares. Finally, we computed the mean average percentage error for both models. The mean average percentage error was lower for the power model than for the linear model in both studies (0.39 vs. 0.44, $t = 3.9$, $P < 0.01$ in study 1 and 0.30 vs. 0.33, $t = 8.3$, $P < 0.001$ in study 2).

To test whether overweight and normal-weight participants estimate calories differently, we fitted a moderated regression: $(\ln(E) = \alpha + \beta \times \ln(A) + \gamma \times \text{OVERW} + \delta \times \ln(A) \times \text{OVERW})$, where OVERW is a binary variable indicating whether the individual is overweight (OVERW = 1) or is of normal weight (OVERW = 0). Statistical tests of the γ coefficient show whether the estimations of overweight and normal-weight participants are statistically different once the actual size of the meal is controlled for. Statistical tests of the δ coefficient show whether changes in meal size affect the estimations of overweight and normal-weight participants in a statistically different way.

As shown in the **Appendix Table**, the γ coefficient was not statistically different from 0 in both study 1 ($t = -0.59$; $P = 0.55$) and study 2 ($t = 1.16$; $P = 0.28$). This shows that once meal size is controlled for, there are no differences in the mean calorie estimations of overweight and normal-weight participants. The interaction coefficient (δ) was also not statistically different from 0 in study 1 ($t = 0.53$; $P = 0.60$) or in study 2 ($t = -1.08$; $P = 0.28$). This shows that increases in meal size similarly influence overweight and normal-weight participants' estimates.

In a final analysis, we examined the sensitivity of these results to possible misspecifications of the overweight categorization caused by the underestimation of self-reported weights. If people tend to underestimate their weights, we would expect that some of the participants with a self-reported BMI between 24 kg/m^{2}and 25 kg/m^2 are actually overweight. We therefore replicated the analyses with a 24-kg/m^2 threshold to categorize people as overweight or normal weight instead of the 25-kg/m^2 threshold that is recommended by the World Health Organization and was used in all other analyses. As the **Appendix Table** shows, our results were very similar in both analyses.

Appendix Table. **Parameter Estimates and Standard Errors in Studies 1 and 2***

Variables	Overweight Threshold, BMI 25 kg/m^2		Overweight Threshold, BMI 24 kg/m^2	
	Study 1	Study 2	Study 1	Study 2
Intercept	2.636 ± 0.781	2.300 ± 0.141	2.288 ± 0.878	2.379 ± 0.144
Actual calories	0.551 ± 0.119	0.637 ± 0.018	0.607 ± 0.134	0.625 ± 0.019
Overweight (1 = yes, 0 = no)	−0.744 ± 1.251	0.277 ± 0.256	0.140 ± 1.198	0.012 ± 0.251
Overweight × actual number of calories	0.098 ± 0.186	−0.036 ± 0.033	−0.035 ± 0.180	0.006 ± 0.033

* All values are reported as mean ± SE. BMI = body mass index.