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BRIEF REPORT

The Effects of Caloric Education, Trial-by-Trial Feedback, and Their Interaction on College-Aged Women's Abilities to Estimate Caloric Content

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Abstract

Background Many people track the caloric content of food, given its relevance to weight loss, gain, or maintenance. A better understanding of the psychological underpinnings of caloric-content estimation for unhealthy foods is of significant psychological and public-health interest.

Purpose This study investigated whether college-aged women could be trained to estimate the caloric content of unhealthy foods more accurately via exposure to caloric-content education, trial-by-trial feedback, and their combination.

Methods The caloric content of 84 foods was estimated and three transfer tasks were completed by 238 undergraduate women. Mixed-effects modeling estimated three aspects of the quadratic function linking true and judged caloric content: threshold (average perceived caloric content), linear sensitivity, and change in sensitivity as caloric content increases.

Results On average, college-aged women underestimated caloric content, demonstrated substantial linear sensitivity to caloric content, and did not show reduced sensitivity as caloric content increased. Trial-by-trial feedback, but not Caloric Education, enhanced caloric estimation on the first two tasks.

Conclusions College-aged women show biased but sensitive judgments of the caloric content of unhealthy food presented in images. Initial evidence suggests that trial-by-trial feedback may be an efficacious strategy to enhance caloric-content estimation, at least when viewing static images of foods.

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Introduction

Many individuals track food's caloric content, given its relevance to body weight [1]. Unhealthy (i.e., processed) foods have more added fat and sugar than nonprocessed foods [2], increasing their caloric content and promoting weight gain. Overweight and obesity are associated with health risks (e.g., coronary artery disease, type 2 diabetes, hypertension, and cancer) [3, 4], as well as psychological concerns (e.g., eating disorders, weight-based discrimination, weight stigma) [5, 6]. Thus, understanding the psychological underpinnings of caloric estimation for unhealthy foods is of significant psychological and public-health interest.

Caloric estimation can be quantified by three parameters: threshold, linear sensitivity, and change in sensitivity as calories increase. Threshold, or the extent to which judged calories consistently under- or over-estimate true calories, is the most frequently examined aspect of caloric estimation. Overall, evidence demonstrates that individuals tend to underestimate caloric content [7], consistent with a "calorie estimation bias" or a maladaptive "threshold."

The current work broadens our understanding of caloric estimation by generalizing the conceptualization, measurement, and analysis of caloric perception from a threshold-only model to a three-parameter model that includes two less-investigated parameters: linear sensitivity and change in sensitivity as calories increase [8, 9]. Linear sensitivity, one's ability to distinguish among various amounts of calories, can be quantified by the slope of the function linking true and judged calories at its intercept, which usually is placed at average true calories. Change in sensitivity is quantified by alteration in the slope of the observed function as actual calories increase. Calorie estimation bias, low linear sensitivity, and decreasing sensitivity as caloric content increases all might foster excess consumption.

A variety of strategies designed to improve normative caloric perception have been evaluated. Unfortunately, calorie menu labeling—one form of caloric education—has shown mixed results at best [10], and talking out loud while estimating calories produced only marginal improvement [11, 12]. In contrast, a piece-meal approach has been relatively more effective [8]. Further, limited prior work has relied on trial-by-trial feedback to enhance caloric estimation [13, 14]. To date, the combination of caloric education and feedback has not been investigated.

The present study examines whether college-aged women could improve their estimation of the caloric content of unhealthy foods via exposure to education and feedback. This study extends prior work [8, 9] by characterizing caloric judgments with a three-parameter model in a highly standardized paradigm using numerous food stimuli that vary in food type (e.g., high added fat, high added sugar) and consistency (i.e., solid or amorphous). Both education and feedback manipulations are computer-based and designed with potential online dissemination in mind. The present study further examines whether any improvement in caloric estimation alters performance on two subsequent calorie estimation tasks and one consumption task.

Methods

Participants

Participants were 273 undergraduate women from the Departmental Research Pool who were fulfilling course requirements. Only females were invited to participate, given their normative concern about weight gain and caloric content. Data from thirty-five women were dropped due to allergies (n = 9) and technical problems (n = 26). The final sample included 238 women, with an average age of 19.18 (SD = 1.29, range = 18–24). The racial and ethnic composition of this sample was 73.2% White/Caucasian, 11% Asian-American, and 15.8% other. Average BMI was 23.76 (SD = 4.24), with 74.2%, 17.6%, and 8.2% meeting criteria for normal weight, overweight, and obesity, respectively.

Session Structure

During the informed consent process, participants were told, "The purpose of the study was to enhance young women's caloric estimation abilities for unhealthy, photographed food using a caloric education module, trial-by-trial feedback, or both." Participants then were seated at a computer in a private cubicle. Using a two-by-two, Education-by-Feedback design, participants were randomized into one of four groups: Group 1 = Both Education and Feedback; Group 2 = Education Only; Group 3 = Feedback Only; and Group 4 = Neither Education nor Feedback. The second half of the session was the same for all groups: all participants completed the Proximal Transfer Task, the Distal Transfer Task, and the Ad Libitum Chocolate Consumption Task. Data were collected between 9:00 am and 6:00 pm. No instructions about food consumption prior to the task were provided to participants, but all participants rated their current hunger level before and after each task (see description of Visual Analogue Scale-Hunger [VAS-H]). This study was approved by the Institutional Review Board at the University of Iowa.

Stimuli

Unhealthy, processed foods (118) that varied in food type (i.e., high added fat, high added sugar, or high added fat and added sugar), consistency (i.e., solid or amorphous), and caloric content were presented in the first two tasks and during the Caloric Education Module. Each food was photographed on a white plate with a 10.25-inch diameter, which was placed on a navy placemat with metallic silverware. Each stimulus was presented once.

Caloric Education Component

Seven educational subsections were included: Introduction to a Calorie, High Fat Foods, High Sugar Foods, High Added Fat and High Added Sugar Foods, Other Nutrients, How the Food is Prepared, and The Influence of Portion Size on Caloric Content. Participants read about each topic and answered questions to engage their attention, to check their understanding, and to reinforce each "caloric content lesson."

Measures

Calorie estimation task

Participants estimated the caloric content of 84 foods on a scale ranging from 0 to 1800 calories. For those who received trial-by-trial feedback, the judged food appeared on the top of the screen, and the caloric judgment scale appeared below, with appropriately positioned dots labeled "TRUE CALORIES" and "JUDGED CALORIES."

Proximal transfer task

All participants estimated the caloric content of 25 new, unhealthy foods on the same scale without trial-by-trial feedback.

Distal transfer task

Participants self-served caloric amounts of six, real, processed foods: Nacho Cheese Doritos (high added fat; asked to serve 350 cal), Trail Mix (high added fat; asked to serve 875 cal), Reese's Pieces (high added fat and high added sugar; asked to serve 525 cal), Buncha Crunch (high added fat and high added sugar; asked to serve 165 cal), Skittles (high added sugar; asked to serve 700 cal), and Sour Patch Kids (high added sugar; asked to serve 1050 cal). Participants were presented with two trays, each of which contained six 28-ounce bowls. On each tray, three of the bowls contained a high-fat food, a high-sugar food, and a high-fat/high-sugar food; three empty bowls were labeled with a specific caloric amount. Participants self-served the requested number of calories from the full bowls to the empty bowls. Bowl weight was measured before and after the task to compute served calories.

Ad libitum chocolate consumption

Participants were invited to consume as much or as little as they liked of an 18-ounce bowl of M&M's in 5 min. Regardless of amount consumed, participants waited quietly for 5 min. The weight of the bowl postconsumption was measured to compute the number of total calories consumed.

Visual Analogue Scale-Hunger

Participants drew a vertical line along a 100-mm line anchored by "I am not hungry at all" and "I have never been more hungry" [15]. Hunger scores were calculated by measuring the distance in mm from the beginning of the line to the vertical mark. Participants reported their current hunger five times: prior to the Training task (Hunger 1), prior to the Proximal task (Hunger 2), prior to the Distal task (Hunger 3), prior to the Consumption task (Hunger 4), and after the Consumption task (Hunger 5).

Demographics

Participants completed a personal information questionnaire (PIQ). They reported their height and weight, from which body mass index (BMI) was computed, and indicated whether they had any food allergies or dietary restrictions.

Data Analysis

Three identical mixed-effects models were used to analyze the effects of Education, Feedback, and their interaction on the three parameters (intercept, linear slope, and quadratic slope) characterizing caloric estimates during the first three tasks. Each model was fit using the lmer function in the lme4 package [16] in R [17], with p values and degrees of freedom estimated by the lmerTest package [18]. Effect sizes were calculated using recommended procedures for mixed-effects models [19]. BMI was transformed to normality via its natural log; all continuous predictors were standardized. Dichotomous experimental predictors were effect coded.

The fixed-effects structure for each model included five predictors of the intercept, linear slope, and quadratic terms: the main effects of and the interaction between Education and Feedback, BMI, and Hunger. The maximal random effects structure supported by the data included random intercepts for subject and food, as well as random subject slopes for linear sensitivity and quadratic sensitivity.

A univariate generalized linear model was used to examine the effect of Education, Feedback, and their interaction during the Caloric Estimation Task on the amount consumed during the Ad Libitum Chocolate Consumption Task. Experimental predictors were effect coded. Hunger 4 and the natural log of BMI were included as covariates. All reliable and trend-level findings are reported below.

Results

Calorie Estimation Task

Threshold

The average caloric rating of the average food (575.26) was substantially less than the true average caloric content (757.20), $t\,(117) = -9.566$, $p < .001$, $d = -1.77$ (see Table 1 and Fig. 1A). A positive, substantial effect of Feedback emerged, $B = 87.50$, $p < .001$, $d = 1.45$; the average caloric ratings were 662.76 and 487.76 calories for those who did and did not receive Feedback.

Linear sensitivity to caloric content

Caloric ratings increased by 220.94 for each SD increase in the foods' caloric content, $p < .001$, $d = 2.65$,

Table 1 Mixed-Effects Modeling Results for Calorie Estimation Task

Parameter	Estimate	Standard error	df	*t* value	*p* value	*d* value
Intercept	**575.26**	**19.02**	**117.00**	**30.24**	**<0.001**	**5.59**
TrueCal	**220.94**	**17.71**	**88.30**	**12.48**	**<0.001**	**2.65**
Education	5.88	8.26	218.00	0.71	0.477	0.10
Feedback	**87.50**	**8.19**	**218.00**	**10.68**	**<0.001**	**1.45**
BMI	4.58	8.21	218.10	0.56	0.577	0.08
Hunger	2.22	8.28	218.00	0.27	0.788	0.04
TrueCal_sq	−18.74	17.33	81.30	−1.08	0.283	−0.24
Education*Feedback	−5.99	8.19	218.00	−0.73	0.465	−0.10
TrueCal*Education	0.04	4.12	218.80	0.01	0.992	0.001
TrueCal*Feedback	**39.17**	**4.09**	**218.80**	**9.57**	**<0.001**	**1.29**
TrueCal*BMI	0.91	4.11	219.10	0.22	0.824	0.03
TrueCal*Hunger	0.30	4.14	218.80	0.07	0.942	0.01
Education*TrueCal_sq	3.64	1.96	561.10	1.86	0.064	0.16
Feedback*TrueCal_sq	−3.15	1.94	560.60	−1.62	0.106	−0.14
BMI*TrueCal_sq	1.05	1.95	563.30	0.54	0.593	0.05
Hunger*TrueCal_sq	2.03	1.97	561.40	1.03	0.302	0.09
TrueCal*Edu*Fdbck	−6.13	4.09	218.80	−1.50	0.136	−0.20
TrueCal_sq*Edu*Fdbck	1.81	1.95	560.50	0.93	0.352	0.08

BMI = Body Mass Index (standardized). Edu = Education (effect coded). Fdbck = Trial-by-trial feedback (effect coded). Significant effects are in bold.

demonstrating substantial linear sensitivity. Feedback exerted a positive, considerable effect on linear sensitivity, B = 39.17, p < .001, d = 1.29, whereby those who did and did not receive Feedback increased their average caloric ratings by 260.11 and 181.77 calories, respectively.

Quadratic sensitivity to caloric content

The average quadratic sensitivity to caloric content was −18.74; sensitivity to actual caloric content decreased descriptively, but not statistically, as caloric content increased, p = .238, d = −0.24.

Proximal Transfer Task

The average caloric rating on the Proximal Transfer Task (641.72) was substantially less than the true average caloric content (749.8), t (25.40) = −3.095, p < .001, d = -1.22 (see Supplementary Table 2; Fig. 1B). Feedback had a positive, large effect on the average caloric rating, B = 63.64, p < .001, d = 0.87. Participants showed very strong average linear sensitivity, B = 288.41, p < .001, d = 3.53, and Feedback substantially increased linear sensitivity, p < .001, d = 0.76. Average quadratic sensitivity to caloric content again was negative but not reliably less than zero, B = −35.91, p = .300, d = −0.45.

Distal Transfer Task

The average number of calories served by participants on the Distal Transfer Task (522.13) was substantially less than their true average caloric content (610.83), t (232.34) = −8.60, p < .001, d = −1.13 (see Supplementary Table 3; Fig. 1C). Those who received Feedback served marginally fewer calories (504.42) than those who did not receive Feedback (539.84), p = .088, d = −0.23. Participants showed very strong average linear sensitivity to served caloric content, B = 265.59, p < .001, d = 5.04. Average quadratic sensitivity to caloric content was negative, but not reliably less than zero, B = −5.79, p = .182, d = −0.16.

Ad Libitum Chocolate Consumption Task

Participants on average consumed 11.706 grams of chocolate (SD = 0.995). A moderate-to-large, positive effect of Hunger emerged, F(1, 237) = 53.574, p < .001, n_p^2 = 0.188.

Discussion

This study investigated whether education and feedback improved caloric estimation for unhealthy foods, producing several conclusions about college-aged women's

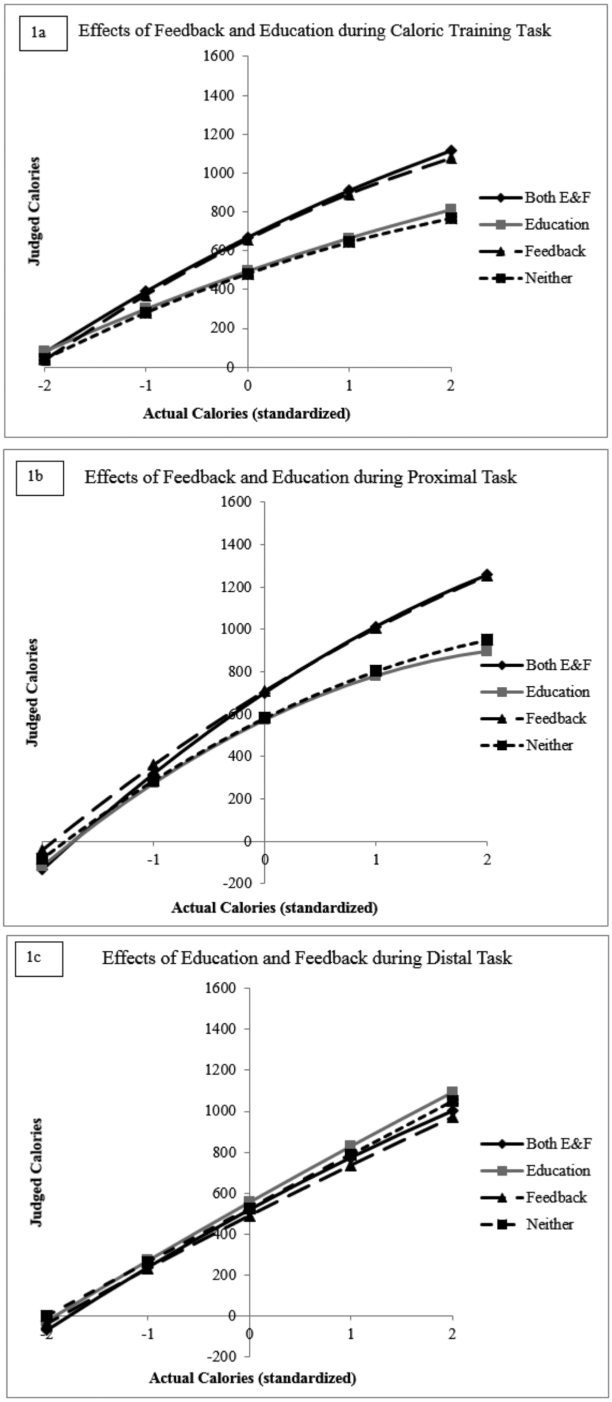

Fig. 1. Model-predicted results for tasks.

normative caloric perceptions. First, they set too low a threshold for caloric estimates across the first two tasks, consistent with prior work [7, 20], which could facilitate overconsumption by suggesting that they are eating fewer calories than they actually are. Second, they demonstrated substantial linear sensitivity to caloric content across the first three tasks. Third, they did not show reduced sensitivity as caloric content increased across tasks. Overall, therefore, college-aged women's normative caloric-content perception is biased but highly sensitive across caloric amounts.

Trial-by-trial feedback substantially improved the biased threshold and linear sensitivity on the training and first transfer tasks. In contrast, completing the educational module did not significantly improve threshold or linear sensitivity to caloric content on either task. This null finding is not entirely surprising, because the informational approach of menu labeling appears inadequate to improve estimation skills [21]. Still, other engaging approaches, beyond what was implemented here, suggest that explicit education on caloric estimation may be beneficial [11, 12].

Feedback and education had no effect on serving and consumption transfer tasks, suggesting that the impact of the currently instantiated feedback strategy may be limited to a computer-based program using photographed stimuli. This underscores that there is a stark contrast between food as encountered in the "real world" and photographed food presented on computers. Further, neither education nor feedback reduced ad libitum consumption of an unhealthy food. In view of the null findings for the serving transfer task, this is not surprising. A moderate-to-large, positive effect of hunger on chocolate consumption did emerge, consistent with past work [22]. Notably, BMI and hunger were unrelated to the three caloric estimation parameters of interest across the first three tasks, which converges with prior work [9].

This study is limited by its reliance on photographed, odorless stimuli for computer-based training purposes, although over one hundred stimuli were presented, and a few real foods were used during the serving and consumption tasks ($n = 9$). Perhaps education and feedback might have influenced serving and consumption behavior if participants had been trained using real foods, but such work could not be disseminated online. The fact that participants were not blind to the purpose of the study may have introduced some bias. Additionally, the duration of the observed effects and the impact of allowing participants to view the same food from multiple perspectives during training procedures remain unknown. The current work is limited in its generalizability, as it was designed to be only a starting point in our larger efforts to investigate efficacious, feasible, and acceptable interventions that improve people's abilities to estimate the caloric content of foods in order to improve eating behavior and health outcomes. As a first step, we were most interested in establishing the average effects of caloric education and trial-by-trial feedback. To accomplish this, we maximized internal validity, studied a narrow sub-population, and assessed only two individual differences variables (i.e., BMI and state hunger) among college-aged women. Critical next steps will be to examine not only the generalizability of these findings to a number of populations, but also to include other variables that have been linked to caloric estimation and weight, including smoking, depression, diet behavior, and weight concern; these may also play a role in shaping caloric estimations, particularly among women, given that women often smoke to maintain weight and their higher prevalence of depression, for example [23].

Despite these limitations, the current work has several noteworthy strengths. First, this study is the first to evaluate whether college-aged women can be trained to improve their caloric estimation skills for unhealthy foods via educational and feedback strategies. Second, evaluating these empirical questions using three-parameter conceptual and analytic models to characterize caloric judgment and serving is novel. Third, this study utilized a large and rigorously developed stimulus set of unhealthy foods. Fourth, the educational module was engaging, interactive, and comprehensive in its content, which enhances our confidence in the null effect of education on bias and sensitivity aspects of caloric estimation. Fifth, study tasks maximized internal validity to the extent possible, while gradually increasing ecological validity in more distal tasks. Sixth, including real foods in two tasks extended prior work non-negligibly.

Several directions for future research should be explored. Foremost is the need to develop online-based feedback and educational approaches that improve bias and sensitivity aspects of caloric serving and consuming in the lab, perhaps by evaluating the efficacy of trial-by-trial feedback via more trials, more stimuli, and more training sessions. Future work should also evaluate the utility of combining the piece-meal approach [11] with trial-by-trial feedback, as it may potentiate the effect of feedback. Although many questions remain, this work addresses several empirical questions about the effects of education and feedback on college-aged women's abilities to estimate caloric content.

Supplementary Material

Supplementary material is available at *Annals of Behavioral Medicine* online.

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Compliance with Ethical Standards

Conflict of interest We certify that there is no conflict of interest with any financial organization regarding the material discussed in this manuscript.

Ethical Approval We certify that this study involving human subjects is in accordance with the Helsinky declaration of 1975 as revised in 2000 and that it has been approved by the relevant institutional Ethical Committee.

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