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Sensitivity to portion size of unhealthy foods

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ABSTRACT

Background: Sensitivity to portion size, a less-investigated aspect of portion size perception, refers to individuals' abilities to distinguish portion sizes of differing amounts.
Objective: The aim of this cross-sectional study is to investigate normative and person-specific aspects of sensitivity to portion size via an evaluation of the perceived healthiness of photographed foods that vary as a function of portion size and food type.
Participants/setting: 272 undergraduate women judged the healthiness of 124 unhealthy food stimuli that varied in portion size (small to extra-large) and food type (Sweets, Fried Foods, and Candies).
Statistical analyses: Multilevel modeling estimated normative sensitivity to portion size, food-specific predictors of participants' sensitivity, and participant-specific predictors of sensitivity.
Results: Participants displayed strong sensitivity to the portion size of unhealthy food, overall, but sensitivity declined as portion size increased. Sensitivity varied as a function of unhealthy food type; participants showed reliably greater sensitivity to portion size for Sweets and Fried Foods than for Candies, although sensitivity to all three food types was substantial. Healthy Food Consumption predicted greater portion-size sensitivity for unhealthy foods at a small-to-moderate level (i.e., those who reported consuming more fruits and vegetables showed greater portion-size sensitivity). A parallel analysis of sensitivity to caloric content, rather than portion size, produced highly similar findings.
Conclusions: When judging food healthiness, college-aged women distinguished well between unhealthy foods with small-to-moderate portion sizes, but their discriminative abilities faltered as portion sizes increased. Healthy Food Consumption was associated with greater sensitivity to portion size for unhealthy food. Future public-health campaigns should highlight the significance of inaccurate portion-size estimation and continue to develop strategies that enhance sensitivity to portion size.

1. Introduction

The public tends to misperceive portion size (Burger, Cornier, Ingebrigtsen, & Johnson, 2011; Faulkner et al., 2013; Just & Wansink, 2013). When characterizing stimulus perception, two parameters typically are estimated: threshold and sensitivity (Macmillan & Creelman, 1991). Much extant literature on portion-size perception has focused only on "portion distortion," which reflects a maladaptive *threshold* for what constitutes an appropriate portion, such that the size of a single portion is overestimated (Lucus, 2008). For instance, in one study, 186 adults overestimated the portion sizes of six foods by 28–71% greater than recommended amounts (Faulkner et al., 2013).

The current work focuses instead on *sensitivity* to portion size, a less-investigated aspect of portion-size perception. As detailed below, linear sensitivity to portion size refers to individuals' abilities to distinguish various portion sizes. Lower linear sensitivity to portion size indicates that perceivers have more difficulty distinguishing larger and smaller portion sizes, such that sometimes they perceive larger portions to be smaller, and sometimes they perceive smaller portions be larger. Decreased sensitivity to portion size potentially could increase the likelihood of overconsumption, particularly if portion-size sensitivity declines as portion sizes increase. Therefore, the current work (1) characterizes linear sensitivity to the portion size of unhealthy food, both on average and as portion size increases, (2) evaluates whether portion-size sensitivity varies as a function of the type of unhealthy food, and (3) examines eating-, weight-, and consumption-related individual differences predictors of portion-size sensitivity. We extend prior work in this area, which has relied on caloric-estimation data, by

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examining these questions in the broader context of perceived food healthiness.

1.1. Sensitivity to portion size

Quantitatively, portion-size sensitivity is the strength of the perceived association between portions that vary in size and some index of amount (e.g., ounces or portion) or some index of nutritional quality (e.g., caloric content or healthiness). Suppose that a researcher asks participants to estimate the caloric content of ten unhealthy fast-foods. One might examine how well true caloric content linearly predicts judged caloric content in multilevel regression analyses. The two model parameters would reflect portion-size perception: participant-specific intercepts and participant-specific slopes. The participant-specific intercepts would indicate the extent to which each participant displayed a maladaptive threshold (i.e., "portion distortion"), such that judged caloric content was less than true caloric content for the average food. The participant-specific linear slopes, in contrast, would index linear sensitivity to portion size, or each participant's average ability to distinguish foods according to their caloric content. Steeper linear slopes would indicate greater sensitivity to varying amounts of food (i.e., greater portion-size sensitivity), whereas shallower slopes would indicate that respondents have more difficulty distinguishing differences in food amount. Notably, portion-size sensitivity can also be characterized by the change in the rate of change in the dependent variable (e.g., caloric content or healthiness ratings) associated with a one-unit increase in the food's portion size. In the current work, for example, we evaluate not only the magnitude of linear sensitivity to portion size, but also whether sensitivity declines as portion sizes increase.

Fig. 1, with portion size on the *X*-axis, and healthiness rating on the *Y*-axis, illustrates threshold for and sensitivity to portion size for four hypothetical participants. Each participant's threshold is indicated by the intercept for the participant's regression line, which is marked with a dot on the figure. The intercept indexes the perceived healthiness of the average-sized food (i.e., where a vertical, dotted line crosses the *X*-axis). In this illustration, Participant D perceives the healthiness of the average-sized food to be significantly greater than Participants A, B, and C. In contrast, the slope of each line provides an index of linear sensitivity to portion size. We would anticipate that healthiness ratings would decline as the portion size of unhealthy food increases, producing a negative slope. The steepness of the slope indicates the magnitude of a participant's linear sensitivity. All four participants

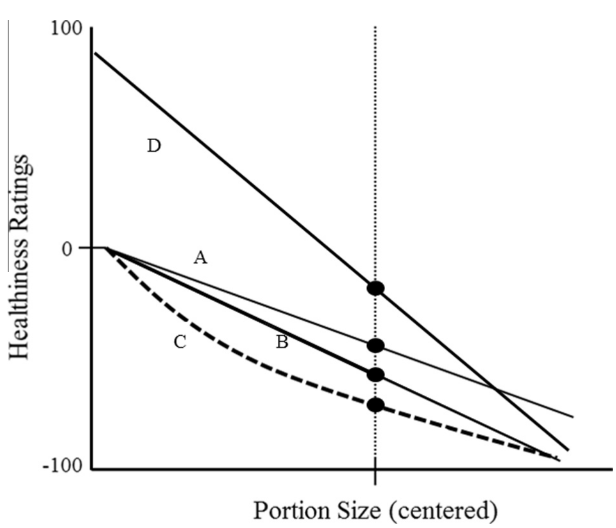

Fig. 1. Sensitivity to portion-size for four hypothetical participants.

demonstrate linear sensitivity to portion size, as evidenced by their negative linear slopes. Participant D has a very steep slope, indicating near-maximal portion-size sensitivity. In contrast, the remaining participants show shallower slopes, indicating less extreme portion-size sensitivity. Note also that Participant C shows a subtly different aspect of portion-size sensitivity: declining sensitivity as portion size increases (i.e., her slope becomes shallower as portion size increases). When portion sizes are small, she shows substantial sensitivity, but she shows weak sensitivity when portion sizes are large. In other words, as food amounts increase, Participant C's healthiness ratings begin to plateau gradually, which reflects that she is less able to distinguish among larger portion sizes.

1.2. Sensitivity to portion size as a function of caloric content

Chandon and Wansink (2007) investigated perception of portion size via calorie estimation across normal-weight and overweight participants. Fifty-five students estimated the size of eight fast food meals of varying sizes. As expected, students underestimated the number of calories in each fast food meal by an average of 139 calories, consistent with a biased threshold for estimating caloric content. The magnitude of the link between true and judged caloric content was strong, indicating substantial sensitivity overall to caloric content. The level of sensitivity to caloric content declined as portion sizes increased, however, indicating that participants were less able to distinguish greater and lesser caloric amounts when portion sizes were larger (Chandon & Wansink, 2007). From a public-health perspective, this could prove problematic as available portion sizes continue to increase, because persons might be less able to recognize the extent to which they engage in excess consumption as portion sizes increase.

Chandon and Wansink (2007) also documented that participants' body mass indices (BMIs) were unrelated to either the threshold for caloric content or sensitivity to caloric content. Prior work had suggested that those with a higher BMI underestimated calories to a greater degree than their low BMI peers (see Livingstone & Black, 2003 for a review). However, Chandon and Wansink noted that in this prior work participants had been asked to report on the caloric content of meals they had self-selected to consume, raising the possibility that BMI-linked variation in selected – rather than perceived – meal size accounted for the results. This highlights the importance of examining perception of food amounts using standardized stimuli.

1.3. Sensitivity to portion size as a function of healthiness ratings

A paucity of research has examined sensitivity to portion size. Only Chandon and Wansink (2007) have characterized normative sensitivity and evaluated whether individual differences in sensitivity are associated with BMI. The current study extends prior work by investigating normative (i.e., average or nomothetic) and person-specific (i.e., idiographic) aspects of the perceived *healthiness* of foods that vary in portion size and nutritional content.

We focus on the perceived healthiness of foods, rather than on their estimated caloric content, as perceived healthiness broadly represents both the caloric and nutritional content of foods. Limited research has focused on perceptions of food healthiness (Paquette, 2005). However, perceived healthiness has been linked to food selection and food consumption (Gravel et al., 2012; Hoefkens, Verbeke, & Camp, 2011; Velazquez, Pasch, Ranjit, & Mirchandani, 2011). The perceived healthiness of various portion sizes may mediate the observed association between increased consumption and the availability of larger portions (i.e., the portion-size effect) (Marchiori, Papies, & Klein, 2014; Spanos, Kenda, & Vartanian, 2015). The current work aims to isolate perception of portion size, which presumably occurs prior to consumption. Therefore, an evaluation of participants' healthiness ratings as a function of portion size may help elucidate the link between perception and potential consumption.

Chandon and Wansink (2007) have argued persuasively that theories founded in psychophysics provide further support for the investigation of portion-size sensitivity as a function of nutritional quality, such as caloric content. Stevens' "empirical law of sensation" (1986) describes the relationship between objective and subjective magnitudes. Notably, the psychophysical function consistent with this theory is a compressive power function, which predicts that people underestimate objective magnitudes to a greater degree as they increase. The vast majority of the literature on subjective sensation concludes that sensation perception is compressive. For instance, people perceive a second candle as adding less brightness than a first candle (Chandon & Wansink, 2007). However, this does not necessitate a cut-off or a threshold for brightness. Rather, it suggests that sensitivity to brightness declines as light intensity increases. The same may be true for sensitivity to portion size via perceived healthiness. The use of analytic models that allow compression of subjective evaluations as magnitude increases, such as those employed by Chandon and Wansink (2007), as well as in the current study, afford examination of portion-size sensitivity using healthiness ratings.

Prior work presented a limited number of stimuli to participants, most of which were fried foods (Chandon & Wansink, 2007). To extend prior work, we ask participants to rate the perceived healthiness of a much larger, more representative set of unhealthy foods that vary in their nutritional content. By enhancing the ecological validity of the stimulus set, the generalizability of the findings increases. Additionally, nutrients appear to be differentially related to healthiness judgments, highlighting the importance of including a diverse array of unhealthy foods in the stimulus set. For example, young women's healthiness judgments are associated with the fat, sugar, and fiber content of food (Rizk & Treat, 2014).

1.4. The current study

The current study uses healthiness ratings to address three aims: (1) to assess normative portion-size sensitivity, both average linear sensitivity and any change in sensitivity as portion sizes increase; (2) to evaluate whether linear sensitivity varies across food type; and (3) to evaluate the association between individual differences and portion-size sensitivity. In the present work, participants judge the healthiness of photos of three types of unhealthy foods (i.e., Fried Foods, Candies, and Sweets) that vary in portion size. Three or four portions are included for each of the foods.

We focus in the current work on portion-size sensitivity for unhealthy foods, recognizing that their consumption is likely more linked to obesity, and that much prior work has focused primarily on them (e.g., Block et al., 2013; Brogden & Almiron-Roig, 2011; Bryant & Dundes, 2005; Geier, Rozin, & Doros, 2006; Hernández et al., 2006; Just & Wansink, 2013). Thus, we include numerous foods that are classified as unhealthy based on their level of processing (i.e., they contained significant added fat or added sugar). Participants use a labeled magnitude scale (LMS), allowing us to obtain ratio-scale healthiness judgments (Rizk & Treat, 2014).

In our primary multilevel analysis of unhealthy food perception, we estimate (a) participants' linear sensitivity to portion size when judging healthiness, as well as any potential reduction in sensitivity as portion size increases (level one); (b) food-specific predictors of linear sensitivity to portion size (level two); and (c) participant-specific predictors of linear sensitivity to portion size (level three).

1.5. Hypotheses

Consistent with prior work (Chandon & Wansink, 2007), at a normative level, we hypothesize that participants will show (1) substantial linear sensitivity to portion size; and (2) declining sensitivity as portion sizes increase. That is, we expect individuals to show strong portion-size sensitivity on average. We also expect them to be able to distinguish well between small and medium portion sizes, as demonstrated by larger differences between their healthiness ratings for small-and medium-sized portions. However, as portion sizes increase, we expect participants to be less sensitive to portion size, as indicated by smaller differences between healthiness ratings for large and very large portion sizes. Similar results to those reported by Chandon and Wansink (2007) would provide strong converging evidence for the validity of healthiness ratings, in spite of their greater subjectivity than the caloric estimates. We also examine caloric content as a predictor of healthiness ratings to evaluate whether any reductions in linear portion-size sensitivity are an artifact of the caloric content in presented foods. Declining sensitivity as portion sizes increase could foster overconsumption, given that individuals may be less able to recognize just how unhealthy the larger portions have become. We also explore whether portion-size sensitivity varies across classes of unhealthy foods (i.e., Sweets, Fried Foods, and Candies).

At the person-specific level, we explore potential individual differences predictors of sensitivity to portion size when judging the healthiness of unhealthy foods in college-aged women. We investigate whether BMI is unrelated to linear portion-size sensitivity when participants judge food healthiness. On the basis of past research (Chandon & Wansink, 2007), we hypothesize that (3a and 3b) BMI will be unrelated to perceptions of healthiness of the average-sized food and to portion-size sensitivity. We also include disordered eating (DE) as a person-specific predictor, given the emphasis placed on increasing consumption of healthy foods and decreasing consumption of unhealthy foods within disordered eating and obesity interventions (Levy, Finch, Crowell, Talley, & Jeffery, 2007; Wadden et al., 2004). DE that is characterized by successful restriction has been associated with judging high-fat foods as less healthy, greater avoidance of high-fat foods, and faster processing of the healthfulness of foods (Schebendach et al., 2014; Steinglass, Foerde, Kostro, Shohamy, & Walsh, 2015; Sullivan, Hutcherson, Harris, & Rangel, 2014). Self-reported DE symptoms have been linked to increased reliance on non-healthful nutrients (i.e., fat) when judging food healthiness (Rizk & Treat, 2014). Therefore, we evaluate the hypothesis that (4) DE will be negatively related to perceptions of healthiness of the average-sized food, and we explore the association between DE and portion-size sensitivity. We include self-reported consumption of both unhealthy and healthy foods over the last month as potential predictors of portion-size sensitivity, as dietary health preventative behavior (such as Healthy Food Consumption) may be influenced in part by nutritional knowledge (such as linear portion-size sensitivity) (Petrovici & Ritson, 2006). Attitudes favoring healthy lifestyle choices have been linked to Healthy Food Consumption (Hearty, McCarthy, Kearney, & Gibney, 2007; see Spronk, Kullen, Burdon, & O'Connor, 2014 for a review). Further, individuals who engage in health behaviors are more likely to use nutritional labels correctly, to understand the link between excessive consumption and health problems, to buy nutritious foods, and to value the importance of a healthy diet (Lin, Lee, & Yen, 2004). Thus, we hypothesize that Healthy Food Consumption (5a) will be negatively associated with perceptions of food healthiness of the average-sized food, and (5b) will be associated with greater linear sensitivity to portion size. We also explore whether state hunger predicts portion-size sensitivity for unhealthy foods, given that state hunger is associated with perceptions of food (Brogden & Almiron-Roig, 2011; Brunstrom, Rogers, Pothos, Calitri, & Tapper, 2008; Shimizu, Payne, & Wansink, 2010). To our knowledge, this is the first study to investigate simultaneously both normative and person-specific sensitivity to food healthiness as portion size varies across three types of unhealthy food via the use of numerous standardized stimuli.

2. Methods

2.1. Participants

Two methods were used for participant recruitment. First, undergraduate females were invited to participate via the Department of Psychology Research Pool, which consists of undergraduates enrolled in relevant psychology classes. Because healthiness ratings could be influenced by one's recommended daily caloric intake, we attempted to hold this variable relatively constant by inviting college females to participate in the study. Second, undergraduate females were invited to participate if they were enrolled in the Department of Psychology Adult Participant Registry. Participants either received partial course credit, or they were paid $12 for their participation. The sample size was selected to afford .80 power to detect moderate-magnitude effects.

2.2. Food stimulus set

Participants viewed 124 photos of 41 foods with 3–4 portion size variations. All foods were processed (i.e., contained either added fat or added sugar). Foods comprised of individual units and amorphous amounts were both included in the stimulus set. Nutritional characteristics were obtained from the nutritional label, food company websites, or www.nutritiondata.com. These 34 unhealthy foods were categorized into three groups: Sweets (added fat and added sugar; e.g., chocolate bars, cookies, powdered donuts), Candies (added sugar and minimal added fat; e.g., Twizzlers, Fruit Loops, gummy bears), and Fried Foods (added fat and minimal added sugar; e.g., French fries, popcorn shrimp, macaroni and cheese). We prioritized ecological validity in the construction of this stimulus set by including a number of prototypical examples from each food category. As detailed below, either three or four portions were presented, depending on the food. Each photo was cropped to provide maximal visibility of the depicted food. Regardless of the portion size presented, the images were 4.6 inches by 4.6 inches on the computer screen viewed by participants. See Fig. 2 for sample stimuli.

For each food, the smallest presented portion size was assigned a value of "1." In most cases, the smallest presented portion size reflected a single serving according to the nutritional label. Remaining portion sizes increased incrementally, depending on the food (e.g., one, two, three, or four cookies; 39 g, 78 g, 117 g, or 156 g of gummy bears). Even the smallest portions available from fast-food companies tend to be too large (Young & Nestle, 2007). Thus, in some cases, the smallest portion size that we presented was less than the smallest portion typically available from fast-food companies. As one example, the "smallest" portion size of Burger King onion rings that we presented was half a box and was assigned a portion-size value of 1.0. A full box received a value of 2, 1.5 boxes received a value of 3, and 2 boxes received a value of 4. Seven unhealthy foods were presented in three portions only (small to large), given that it seemed unlikely that a person would consume an extra-large portion of these foods in the real world (e.g., three, full-sized Hershey's chocolate bars).

The average (SD) number of calories for the smallest portion size varied across food types: 193 (66.11) for Sweets, 226.22 (111.71) for Fried Foods, and 83.79 (25.15) for Candies. A planned contrast revealed that the average caloric content for the smallest portion of Sweets and Fried Foods exceeded that of Candies, $F(2,28) = 5.915$, $p = 0.007$. Note that we did not attempt to equate the average caloric content of the smallest portion size for each food type, even for the unhealthy foods, because this would have compromised the ecological validity of the judged portion sizes. If we had done so, either the portion sizes for Candies would have been enormous or the portion sizes for Sweets and Fried Foods would have been extremely small.

2.3. Healthiness rating task

Participants rated the healthiness of each food stimulus in its given amount, as perceived by her at that moment in time, on a scale anchored by "the most healthy food imaginable" (100) and "the most unhealthy food imaginable" (−100). Participants imagined stimuli for each end of the scale before beginning the task and then use these imagined stimuli as reference points while making their ratings. More specifically, participants were asked, "How healthy or unhealthy is this food (IN THIS AMOUNT), relative to the healthiest and unhealthiest foods imaginable?" Intermediate anchors were spaced appropriately to obtain ratio-scale judgments. Unlike Likert-scale measures, the labeled magnitude scale allowed for valid comparisons of participants' healthiness judgments; asking participants to rate each food relative to their own examples of the healthiest and unhealthiest foods reduces potential individual differences confounds in anchor interpretations (Bartoshuk et al., 2004; Rizk & Treat, 2014). The food stimuli were presented in a random order. The task took approximately twenty minutes to complete.

2.4. Measures

2.4.1. Eating Disorder Examination-Questionnaire (EDE-Q)

The EDE-Q (Fairburn & Beglin, 1994) is a 39-item questionnaire comprised of four subscales (Restraint, Eating Concern, Weight Concern, and Shape Concern), from which a global disordered eating score is calculated. Participants endorse responses on a 0–6 Likert-type scale. The EDE-Q has been shown to be internally consistent, reliable, and valid (Bardone-Cone & Boyd, 2007; Peterson et al., 2007). Higher scores indicate greater pathology; a score greater than or equal to 4 is recommended as the clinical cut-off (Fairburn & Beglin, 1994).

2.4.2. Eating Patterns Questionnaire (EPQ)

The EPQ is a measure of food consumption developed for this project to calculate self-reported unhealthy and healthy food intake during the last month. Participants endorsed how frequently they consume Candies, Sweets, Fried Foods, Vegetables, and Fruits. The response options for the EPQ were modeled broadly after the response options on the Diet Behavior and Nutrition Questionnaire in the National Health and Nutrition Examination Survey, 2013 (CDC, 2013). Frequency response categories include never, 1 time per month or less, 2–3 times per month, 1–2 times per week, 3–4 times per week, 5–6 times per week, daily, 2–3 times per day, and 4 or more times per day. Using this information, the frequency of consumption for each category was calculated to reflect consumption frequency per month.

2.4.3. Visual Analogue Scale (VAS)

The VAS (Flint, Raben, Blundell, & Astrup, 2000) is a self-report measure used to assess state hunger. Participants indicated their current hunger by drawing a vertical line somewhere along on a

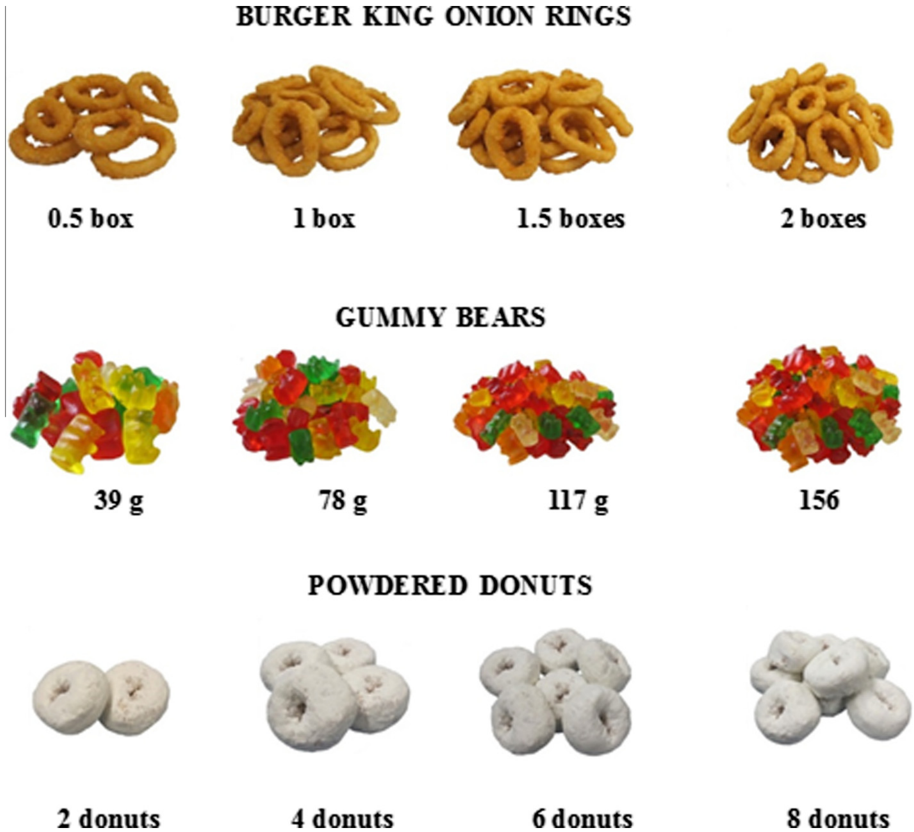

Fig. 2. Sample stimuli that vary in portion size and food type. *Note:* The values of the presented portion sizes for all three food types are 1, 2, 3, and 4, respectively.

100 mm horizontal line, which is anchored by "I am not hungry at all" (0 mm) and "I have never been more hungry" (100 mm). State hunger was quantified by measuring where the vertical line is placed; higher numbers indicated greater state hunger.

2.4.4. Personal Information Questionnaire (PIQ)

The PIQ assesses demographic data, including age, education, race/ethnicity, and current height and weight. Height and weight were used to calculate BMI for each participant.

2.5. Procedure

After obtaining informed consent, participants completed the VAS, the Healthiness Rating Task, the EDE-Q, the EPQ, and the PIQ. This study was approved by the Institutional Review Board at the University of Iowa.

3. Statistical analysis

Hierarchical linear modeling (Raudenbush & Bryk, 2002) with robust standard errors was used to analyze women's perceptions of the healthiness of foods as a function of their portion size. More traditional analytic techniques are inappropriate, given the inclusion of both discrete and continuous predictors, as well as the nested structure of the current data set, in which portion sizes were nested within foods, which were nested within participant. A 3-level regression analysis was conducted. The analysis consisted of participants' ratings of the healthiness of foods of 3 or 4 portion sizes at level one, which were nested within 34 unhealthy foods at level two, which were nested within 272 participants at level three. Given the hierarchical nature of the model, predictors were included at their appropriate level. For example, all between-subject influences were included at the highest level of the model (level 3), which quantified participant-specific influences on healthiness perception. All food-specific influences were included at the middle level of the model (level 2), which quantified the effects of food-related influences on healthiness perception. Finally, portion-size and its square were included as predictors at the lowest level of the model (level 1), which specified the influence of portion size on perceived healthiness.

This analytic approach allowed us to evaluate simultaneously but separately the normative (or nomothetic) influences of portion size on participants' ratings of food healthiness (at level one), the normative influences of specific food types (i.e., Sweets, Fried Foods, Candies) on linear sensitivity to portion size (at level two), and the person-specific influences of BMI, etc., on each participant's linear sensitivity to portion size (at level three). There were no missing data. We provide Cohen's *d* indices of effect-size magnitude for all effects and rely on conventional cutoffs for small (.2), medium (.5), and large (.8) effect sizes when characterizing the magnitude of effects. These values were computed using procedures recommended in (Oishi, Lun, & Sherman, 2007).

3.1. Sensitivity to portion size for unhealthy foods

To evaluate Hypotheses 1 and 2, the level-one equation below specified portion size (centered) and the square of (centered) portion size as predictors of each participant's food healthiness ratings. The intercept for the level-one equation, π_0, reflected a participant's healthiness rating for an unhealthy food with an average portion size. Thus, one participant might judge the healthiness of the average-sized food unhealthy food to be about −30, whereas another participant might judge the average-sized unhealthy food to be less healthy, with a value of −40. The linear slope in the level-one equation, π_1, indexed average linear sensitivity to portion size at the intercept – that is, the change in healthiness ratings associated with a one-unit increase in the portion size of the average-sized food. According to Hypothesis 1, we anticipated that participants would exhibit strong linear sensitivity to portion size, as evidenced by a significant and large-magnitude negative linear slope. The quadratic slope, π_2, indexed the change in sensitivity as a function of portion size – that is, change in the rate of change in healthiness ratings associated with a one-unit increase in the food's portion size. A value of zero indicated a linear relationship between portion size and healthiness ratings, such that there was no change in sensitivity as portion size increased. Positive values indicated that portion size sensitivity declined as portion size increased; in other words, the change in the rate of change of healthiness ratings *declined* as portion became larger. Finally, negative values indicated that sensitivity to portion size increased as portion size increased; in other words, the change in the rate of change of healthiness ratings *increased* as portion sizes increased. According to Hypothesis 2, we anticipated that participants would exhibit decreasing sensitivity as portion size increases, as evidenced by a significant positive acceleration slope and a convex non-linear function.

Level-one equation for portion size as a predictor of perceived food healthiness:

$$\text{Healthiness rating} = \pi_0 + \pi_1(\text{portion size}) + \pi_2(\text{portion size})^2 + r$$

The level-two equations below specified the relationships between each of the level-one parameters and three types of unhealthy foods: Sweets, Fried Foods, and Candies. These food types were dummy-coded, using Sweets as the reference group. The first level-two equation examined these food-specific predictors of variability in the judged healthiness of a food with an average portion size. For example, the regression coefficient for Fried Foods in the first equation, β_{01}, indicated the model-predicted difference in the rated healthiness of Fried Foods versus Sweets with an average portion size. The second level-two equation evaluated these food-specific predictors of sensitivity to portion size. For example, β_{12} indicated the difference in linear sensitivity to portion size for Candies versus Sweets. The acceleration term was treated as a fixed effect without predictors, because preliminary analyses indicated very strong correlations between the random effects for the linear and quadratic slopes.

Level-two equations for food-type predictors of level-one parameters:

$$\pi_0 = \beta_{00} + \beta_{01}(\text{Fried Food}) + \beta_{02}(\text{Candy}) + u_0$$
$$\pi_1 = \beta_{10} + \beta_{11}(\text{Fried Food}) + \beta_{12}(\text{Candy}) + u_1$$
$$\pi_2 = \beta_{20}$$

To address Hypotheses 3–5, the level-three equations specified the influence of five individual-differences predictors on portion-size threshold and linear sensitivity: BMI (natural log transformed and centered), EDE-Q (centered), Unhealthy Food Consumption (UNH_Consume; centered), and Healthy Food Consumption (H_Consume; centered), and Hunger (centered). A principle components analysis was used to create the two consumption composite scores from participant reports of the frequency with which fried foods, sweets, candies, fruits, and vegetables were consumed.[1] Only the judged healthiness of a food with an average portion size, β_{00}, and linear sensitivity to portion size, β_{10}, were treated as random effects with these five predictors. This simplified the model by focusing on the parameters of primary interest (i.e., the intercept and linear slope in the level-one equation). The intercept for β_{00}, γ_{000}, indicated the healthiness rating for a food with an average portion size for a participant with average BMI, EDE-Q, consumption scores, and state hunger. According to Hypothesis 3a, we expected a null finding for BMI, as evidenced by a non-significant effect of BMI on the intercept term, which indexed the perceived healthiness of the average-sized food. However, according to Hypothesis 4, we anticipated that DE symptoms would negatively predict the perceived healthiness of the average-sized food, demonstrated by a significant, negative effect on the intercept term. According to Hypothesis 5a, we expected that Healthy Food Consumption would also negatively predict the perceived healthiness of the average-sized food, demonstrated by a significant, negative effect on the intercept term.

The intercept for β_{10}, γ_{100}, indicated the linear portion-size sensitivity of a participant with average BMI, EDE-Q, consumption scores, and state hunger. The partial-slope estimates in these equations indicated the association between the relevant parameter and the individual-differences variables. For example, γ_{103} specified the association between linear sensitivity to portion size and consumption of unhealthy foods. According to Hypothesis 3b, we expected a null finding for BMI, as evidenced by its non-significant effect on the linear slope for portion size. We also explored whether EDE-Q had an effect on the linear slope for portion size. Finally, according to Hypothesis 5b, we expected that Healthy Food Consumption would have a significant, negative effect on the linear slope for portion size, which would reflect greater linear portion-size sensitivity.

Level-three equations for participant-specific predictors of level-one parameters:

$$\beta_{00} = \gamma_{000} + \gamma_{001}(\text{BMI}) + \gamma_{002}(\text{EDE-Q}) + \gamma_{003}(\text{UNH\_Consume})$$
$$+\gamma_{004}(\text{H\_Consume})$$
$$+\gamma_{005}(\text{Hunger}) + u_0$$
$$\beta_{01} = \gamma_{010}$$
$$\beta_{02} = \gamma_{020}$$
$$\beta_{10} = \gamma_{100} + \gamma_{101}(\text{BMI}) + \gamma_{102}(\text{EDE-Q}) + \gamma_{103}(\text{UNH\_Consume})$$
$$+\gamma_{104}(\text{H\_Consume})$$
$$+\gamma_{005}(\text{Hunger}) + u_0$$
$$\beta_{11} = \gamma_{110}$$
$$\beta_{12} = \gamma_{120}$$
$$\beta_{20} = \gamma_{200}$$

4. Results

4.1. Sample characteristics

Two hundred and seventy-two (272) undergraduate women with a mean age of 18.91 years (SD = 1.26) participated in this study. The racial/ethnic breakdown of the sample was 81.1% White/Caucasian, 10.9% Asian-American, 3.2% Black/African American, and 4.8% Other. The average BMI was 23.23, ranging from 16.52 to 50.06, with 5.4% of the sample meeting criteria for underweight, 11.3% of the sample meeting criteria for overweight, and 8.3% of the sample meeting criteria for obesity. 8.5% of the sample self-reported clinically significant eating-related difficulties, according to the EDE-Q. In the current sample, the mean (SD) number of times per month each food type was consumed was 12.59 (11.52) for Sweets, 9.17 (7.89) for Fried Foods, 10.5 (13.9) for Candies, 33.52 (27.35) for Fruits, and 26.72 (23.50) for Vegetables. Finally, average state hunger in the sample was 31.55.

[1] As expected, the principal components analysis extracted two components with eigenvalues greater than 1.0 (1.749, 1.684). The two orthogonally rotated components accounted for 68.66% of the variability in the consumption data. Candies, Sweets, and Fried Foods loaded strongly on the first component (.76, .76, .75), which we labeled Unhealthy Food Consumption, but loaded minimally on the second component (−.05, .11, −.08), which we labeled Healthy Food Consumption. In contrast, Vegetables and Fruits loaded extremely strongly on the second component (.92, .92), but very weakly on the first component (.001, −.03). Regression-based scores were computed for each participant for each of the two composites, Unhealthy Food Consumption and Healthy Food Consumption.

4.2. Perceived healthiness of varying portions of unhealthy foods

Table 1 presents the results of the modeling, organized by the three level-one parameters (i.e., the intercept, the linear term for portion size, and the quadratic (or acceleration) term for portion size).

4.2.1. Normative results

Fig. 3 depicts the normative non-linear functions linking portion size and healthiness ratings for Sweets, Fried Foods, and Candies. The average healthiness rating for Sweets, γ_{000}, was −37.002, indicating that the average participant judged the healthiness of the average-sized Sweet to be −37.002 units below zero, the mid-point of the healthiness scale. The average-sized Fried Food was deemed to be similarly unhealthy, with an average rating of −35.403. The average-sized candy was judged to be much less unhealthy, on average, with an intercept of −19.301, consistent with the lower caloric content of the Candies.

The average linear sensitivity to portion size for Sweets, γ_{100}, was −7.666 (d = −2.749), indicating that participants' healthiness

Table 1
Multilevel modeling results for unhealthy foods (Fried Foods, Candies, Sweets).

Parameter	Estimate	Standard error	t Value	df	p Value	d Value
For intercept, π_0						
For intercept, β_{00}						
Intercept, γ_{000}	−37.002	0.941	−39.333	264	<0.001	−4.842
BMI, γ_{001}	4.323	3.801	1.137	264	0.256	0.140
EDE-Q, γ_{002}	−1.855	0.564	−3.290	264	<0.001	−0.405
UNH_Consume, γ_{003}	−0.113	0.644	−0.175	264	0.861	−0.022
H_Consume, γ_{004}	−2.026	0.615	−3.285	264	0.001	−0.404
Hunger, γ_{005}	0.013	0.029	0.451	264	0.652	0.055
For Fried Foods slope, β_{01}						
Intercept, γ_{010}	1.599	0.735	2.175	7016	0.030	0.268
For Candies slope, β_{02}						
Intercept, γ_{020}	17.701	0.767	23.080	7016	<0.001	2.841
For portion size slope, π_1						
For intercept, β_{10}						
Intercept, γ_{100}	−7.666	0.343	−22.329	264	<0.001	−2.749
BMI, γ_{101}	−1.997	1.361	−1.468	264	0.143	−0.181
EDE-Q, γ_{102}	−0.100	0.150	−0.666	264	0.506	−0.082
UNH_Consume, γ_{103}	−0.045	0.151	−0.295	264	0.769	−0.036
H_Consume, γ_{104}	−0.644	0.172	−3.733	264	<0.001	−0.460
Hunger, γ_{005}	0.004	0.007	0.505	264	0.614	0.062
For Fried Foods slope, β_{11}						
Intercept, γ_{110}	2.035	0.252	8.066	7016	<0.001	0.993
For Candies slope, β_{12}						
Intercept, γ_{120}	3.357	0.278	11.960	7016	<0.001	1.472
For acceleration slope, π_2						
For intercept, β_{20}						
Intercept, γ_{200}	0.832	0.084	9.891	12689	<0.001	1.217

Note: EDE-Q = Eating Disorders Examination-Questionnaire; UNH_Consume = Unhealthy Food Consumption; H_Consume = Healthy Food Consumption.

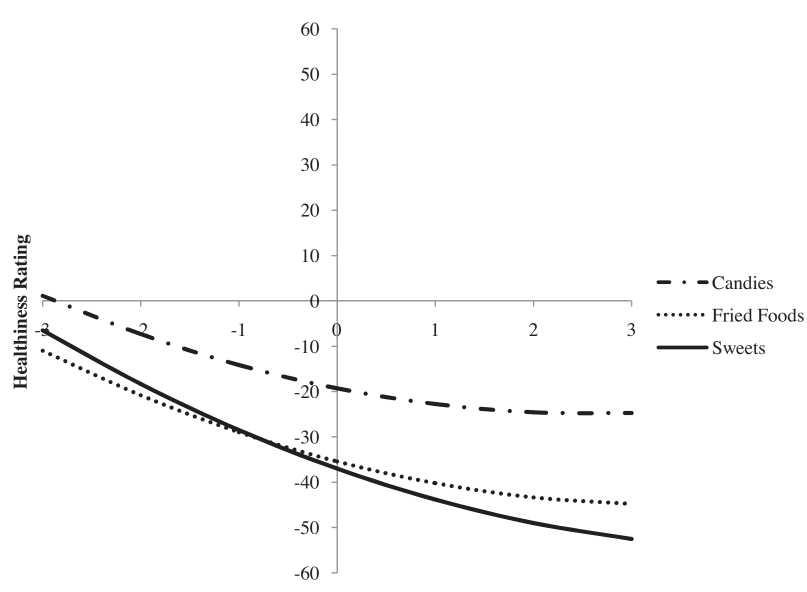

Fig. 3. Normative relationship between portion size and healthiness ratings.

ratings decreased by 7.666 for each one-unit increase in the portion size of Sweets. Average linear sensitivities to the portion size of Fried Foods and Candies were significantly lower, at −5.631 ($t(264) = -22.329$, $p < 0.001$, $d = 0.993$) and −4.309 ($t(7016) = 8.066$, $p < 0.001$, $d = -1.472$), respectively. However, the magnitude of the linear sensitivity to the portion sizes of all three unhealthy food types ($ds = -2.749, -3.193, -2.902$) demonstrated that participants showed substantial linear sensitivity to portion size for unhealthy foods. This is consistent with Hypothesis 1 and indicates that healthiness ratings are diagnostic with respect to linear portion-size sensitivity. Importantly, at the individual subject level, all participants showed sensitivity values less than zero (i.e., they all showed significant linear sensitivity), and their healthiness ratings declined continuously, highlighting the appropriateness of the non-linear function we fit to the data.

Finally, at a normative level, the average change in sensitivity to portion size, γ_{200}, was 0.832 ($d = 1.217$), indicating that as portion size increased, sensitivity to portion size declined sharply, consistent with Hypothesis 2.

4.2.2. Person-specific results

Consistent with Hypothesis 3a, BMI did not emerge as a participant-specific predictor of the perceived healthiness of the average-sized unhealthy food. In contrast, EDE-Q was a negative, small-to-moderate magnitude predictor of healthiness ratings for the average-sized unhealthy food (γ_{002}, $d = -0.405$, $p < 0.001$); those reporting more DE symptoms judged an average-sized unhealthy food to be moderately more unhealthy than those reporting fewer symptoms, consistent with Hypothesis 4. H_Consume also negatively predicted the judged healthiness of an average-sized food at a small-to-moderate level (γ_{004}, $d = -0.404$, $p = 0.001$); participants who consumed more fruits and vegetables viewed the average-sized unhealthy food to be less healthy than those who consumed less fruits and vegetables, consistent with Hypothesis 5a.

Consumption of healthy foods also reliably predicted linear sensitivity to portion size (γ_{104}, $d = -0.460$, $p < 0.001$) at a small-to-moderate level. Thus, participants who reported consuming more fruits and vegetables showed greater portion-size sensitivity when judging the healthiness of unhealthy foods, consistent with Hypothesis 5b. Neither BMI nor EDE-Q was associated with linear portion-size sensitivity, consistent with Hypothesis 3b.

5. Discussion

This study explored participants' linear sensitivity to the portion size of 34 unhealthy foods when judging healthiness, as well as reduction in sensitivity as portion size increased, within a sample of college-aged women. Additionally, multilevel modeling techniques were used to estimate food-specific and participant-specific predictors of participants' linear sensitivity to portion size for unhealthy foods.

5.1. Sensitivity to portion size declined as portion size increased

As expected, college-aged women showed substantial linear sensitivity to portion size for unhealthy foods. Also as expected, participants were able to distinguish foods that were extra-small to medium in size in terms of their perceived healthiness, but participants' sensitivity to portion size declined gradually as portion size increased. In other words, participants were less able to discriminate the healthiness of foods for particularly large portions. These findings are consistent with prior work, which suggested that sensitivity to the caloric content of unhealthy foods declines as portion sizes increased (Chandon & Wansink, 2007). The current work extends the previous findings by demonstrating the same phenomena using healthiness judgments, which are broader than caloric estimates. Moreover, the present work included a noteworthy number of standardized stimuli, in an effort to enhance the external validity of the findings. A reduction in portion-size sensitivity as portion sizes increase could prove problematic. College-aged women might not perceive the extent to which frequent consumption of large portions is a non-healthful behavior, which is concerning given the easy accessibility of large amounts of food (Young & Nestle, 2012).

5.2. Robust linear sensitivity to portion size across all unhealthy food types

In terms of food-specific predictors for unhealthy foods, participants demonstrated considerable sensitivity to portion size across all three food types. This finding extends the work of Chandon and Wansink (2007) who evaluated portion-size sensitivity to the caloric content of fried foods only. Moreover, participants showed reliably greater linear sensitivity to varying portion sizes for Sweets and Fried Foods than for Candies. Encouragingly, this finding suggests that individuals are aware of the lack of health benefits provided in high-fat, high-sugar foods. However, college-aged women seem less able to distinguish the additional sugar content in varying portions of Candies, a high-sugar food, relative to Sweets and Fried Foods. Because Candies differed from Sweets and Fried Foods in caloric content, we ran parallel analyses that used caloric content (rather than portion size) as a predictor of healthiness ratings. The pattern and statistical significance of all findings was the same, indicating that the decreased portion-size sensitivity for Candies was not an artifact of their decreased caloric content. The reliably reduced linear sensitivity to portion size for Candies is consistent with the work of Rizk and Treat (2014), which suggested that college-aged women base their healthiness judgments to a far greater degree on fat than on sugar content. Overall, the robustness of young women's linear sensitivity across all three unhealthy food types highlights the utility of investigating food-specific portion-size sensitivity.

5.3. Individual differences in sensitivity to portion size

Interestingly, BMI was not a reliable individual differences predictor of sensitivity to portion sizes of unhealthy foods. That is, overweight and obese women in the current sample showed similar sensitivity to portion size, when compared with that of their normal-weight peers. This finding converges with the work of Chandon and Wansink (2007), which suggested that BMI was not associated with decreased sensitivity to caloric content for unhealthy fast-foods. Eating meals away-from-home is an increasing phenomenon (Ayala et al., 2008; Guthrie, Lin, & Frazao, 2002), which is problematic, given the ubiquity of over-sized portions in restaurants (Condrasky, Ledikwe, Flood, Rolls, & Flood, 2007) and that overweight and obese persons are more likely to eat away-from-home (De Castro, King, Duarte-Gardea, Gonzalez-Ayala, & Kooshian, 2012). Thus, it is possible that people who struggle with overweight and obesity may benefit more from portion-size sensitivity training programs, because they are more likely to encounter, purchase, and consume larger portion sizes (De Castro et al., 2012; Young & Nestle, 2002). Similarly, state hunger predicted neither the perceived healthiness of the average unhealthy stimulus nor portion-size sensitivity. Thus, whereas state hunger has been associated with the craving and liking of foods (e.g., Gearhardt, Rizk, & Treat, 2014), state hunger was not associated with sensitivity to the portion size of these unhealthy food types.

In contrast, high endorsement of DE symptomatology was a negative, small-to-moderate magnitude predictor of healthiness ratings for the average-sized, unhealthy food. This demonstrates that those with high DE attitudes and behaviors may find the nutritional content of unhealthy foods to be more salient than their peers, which is consistent with theoretical expectations (Urdapilleta, Mirabel-Sarron, Meunier, & Richard, 2005). In future research, it will be important to investigate other person-specific predictors of portion-size sensitivity. For example, portion-size sensitivity may be related to dietary disinhibition and violation of restraint (Polivy & Herman, 1985).

One particularly noteworthy, participant-specific predictor emerged. The consumption of healthy foods negatively predicted the judged healthiness of an average-sized, unhealthy food at a small-to-moderate level. That is, those who consumed more fruits and vegetables, relative to their peers, perceived unhealthy foods to be less healthy. Moreover, healthy-food consumption reliably predicted greater linear sensitivity to portion size of the three unhealthy food types at a small-to-moderate level. These findings are particularly interesting, as they demonstrate a connection between food perception and food consumption through the association between sensitivity and engagement in dietary health behaviors. The causal direction of the relationship between Healthy Food Consumption and sensitivity to portion size cannot be determined in the current work, of course, and remains an important future topic to explore. On the one hand, greater consumption of healthy foods (i.e., fruits and vegetables) might increase the salience of the nutritional content for unhealthy foods. On the other hand, greater awareness of the nutritional content of unhealthy foods might prompt greater consumption of healthy foods.

5.4. Strengths and limitations

The current findings are constrained in their generalizability due to the sample under investigation. The sample lacks variation in age and gender (i.e., absence of males). Although there was some variation in BMI (11.3% overweight and 8.3% obese) and DE symptoms (8.5% reporting clinically significant issues), future research will need to evaluate the generalizability of the current findings to samples of women with a larger percentage of overweight and obesity and to samples reporting more serious eating-and weight-related difficulties (e.g., dietary disinhibition and restraint). Further, the current study evaluated a subset of unhealthy food types and did not include healthy food stimuli. The lack of a sizing guide for the food stimuli (e.g., placement on a uniformly sized plate) is also a limitation, given that individuals are able to compare food amounts to references in the "real world," such as a plate or a table on which food is placed. Additionally, the subjective and complex nature of healthiness ratings (e.g., the lack of an absolute zero point on the scale, an unknown "true" relationship between portion size and healthiness, etc.) constrains the strength of the inferences that can be drawn about them, although we perceive the marked similarity of the current findings to those reported by Chandon and Wansink (2007) on caloric judgments to be quite encouraging regarding their validity.

However, the current work includes several strengths. Reliance on photographic, rather than semantic, food stimuli, improves the ecological validity of the work. Further, by prioritizing the variation of portion size, rather than caloric content, the current work affords a more ecologically valid evaluation of sensitivity to portion size across the three food types. Second, the parallel pattern of findings, whether using portion size or caloric content as predictors of healthiness ratings, bolsters the robustness of the broader conclusions that can be drawn from the work regarding portion-size perception and the validity of the Healthiness Rating Task. Third, the use of the labeled magnitude scale and multilevel modeling methods allowed us to evaluate indirectly (and perhaps, more accurately) the extent to which participants relied on portion size during the healthiness judgment task. Moreover, the indirect approach provided ratio-scale judgments of the foods, which are less vulnerable to individual differences confounds in anchor interpretation (Bartoshuk et al., 2004), thus increasing our confidence in both the observed and null findings. The multilevel modeling techniques also allowed for separate, but simultaneous, examinations of participant-specific and food-specific predictors of sensitivity to portion size.

The subjectivity of healthiness ratings could be construed as a weakness of the current work, but several points mitigate concerns. First, when calories were used as a predictor of healthiness ratings, rather than portion size, the analyses revealed highly similar results for the intercept, slope, and acceleration parameters; the food-specific characteristics; and the individual differences variables. The parallel pattern of results, regardless of predictor, provides support for the potential validity and utility of healthiness ratings as a dependent variable. Second, the use of healthiness ratings is supported by the data: average healthiness ratings for unhealthy foods dropped markedly but continuously as the portion sizes of unhealthy foods increased, consistent with Stevens' empirical law of sensation (Stevens, 1986). Moreover, this pattern of findings was displayed at the individual subject level: every participant showed sensitivity values less than zero, and ratings declined continuously. These normative and individual-specific findings indicate that participants' ratings were not based solely on the nutritional quality of the food irrespective of amount and were inconsistent with a threshold model of perception. Finally, it is important to note the strong degree of convergence between the current work and that of Chandon and Wansink (2007), who showed that sensitivity to caloric content declined as portion size increased, even though participants were sensitive to portion size in general. In other words, even though they focused on an entirely different dependent variable (estimated caloric content), the results were highly similar.

6. Conclusions and future work

The current work extends previous knowledge by assessing sensitivity to the portion sizes of numerous, standardized food stimuli that vary by type. Additionally, the current work explores normative and person-specific correlates of sensitivity to portion size via multilevel modeling techniques. Using an indirect paradigm, this work demonstrates evidence converging with that of Chandon and Wansink (2007) of moderate linear sensitivity to portion size, reduced sensitivity to portion size as portion size increases, and no relationship between BMI and portion-size sensitivity. However, future work should continue to explore sensitivity to unhealthy foods, as individuals may differ in their sensitivity to foods that vary by nutritional content (e.g., high-sodium foods), situational context (e.g., a snack or a single meal), or the specific population for whom healthiness is being judged (e.g., the nutritional needs of an older adult or a young child). In the future, it may prove helpful to ask a large sample of dietitians to provide healthiness ratings, which would provide expert consensus data for use in future data analyses. Moreover, future empirical work should investigate the causal directionality of the person-specific correlates of Healthy Food Consumption with portion-size perception.

Participants' overall linear sensitivity to portion size was strong; however, sensitivity to portion size decreased as portions increased, suggesting that there is potential to improve sensitivity to increasing portion sizes. One way to improve sensitivity would be through training programs. Experimental evaluations of the extent to which portion size training programs can improve sensitivity should be conducted. For example, participants might make healthiness judgments for foods that vary in portion size and receive feedback based on normative data from dieticians. Alternatively, participants might make caloric estimates of various foods and receive trial-by-trial feedback on the true caloric content. Further, the reduction in sensitivity with increasing portion size might be addressed in part by presenting all stimuli on a constant-sized plate, which might enhance the salience of the larger portion sizes. Prior work suggests manipulating characteristics of plates, such as size or rim width, may improve portion-size perception and decrease consumption (McClain et al., 2013; Pratt, Croager, & Rosenberg, 2012). In either case, the data from this study suggest that while participants are sensitive to smaller portion sizes, it may be possible to increase portion-size sensitivity to larger portion sizes. More generally, it might prove helpful to address both portion distortion and declining sensitivity to increasing portions sizes in behavioral weight-loss programs, given the frequency with which high-BMI individuals may be exposed to large portions.

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