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Research report

# What constitutes food variety? Stimulus specificity of food

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ABSTRACT

Variety is a major influence of energy intake, but it is not known how much foods have to vary to influence eating. Using a stimulus specificity habituation paradigm we assessed the influence of varying the texture and appearance of nutritionally identical foods on responding for food and energy intake, and whether sensitization, or an increase in responding prior to habituation, was related to the rate of habituation or recovery of responding. Children responded for elbow macaroni and cheese until they habituated, then were provided either more elbow macaroni and cheese, spiral macaroni and cheese, or chicken nuggets. Children provided chicken nuggets or spiral macaroni and cheese recovered responding in comparison to more elbow macaroni and cheese. Children who sensitized showed slower habituation and consumed more food and more energy than those who did not sensitize, but did not differ in recovery of responding to the chicken nuggets or spiral macaroni and cheese. Results show small variations in food characteristics lead to recovery of responding and increased intake after children have habituated.



Food variety represents one of the most powerful ways to increase energy intake (Epstein, Temple, Roemmich, & Bouton, 2009; Raynor & Epstein, 2001) and habituation provides a theoretical model that can be used to understand why continuing to eat the same food results in reduction of the motivation to consume that food (Epstein, Temple, et al., 2009), while increasing the variety of food consumed results in maintenance of the motivation to eat (Epstein, Robinson, et al., 2009; Epstein, Temple, et al., 2009; Temple, Giacomelli, Roemmich, & Epstein, 2008). Repeated presentation of food results in a reduction in motivated responding to food, and introduction of a new food results in recovery of motivation to eat, and increased energy intake, characteristic of habituation (McSweeney, Hinson, & Cannon, 1996; McSweeney & Swindell, 1999b). Research has focused on presenting novel foods to stimulate recovery. For example, we have shown that children habituate to repeated portions of cheeseburger, and will recover responding for apple pie (Epstein et al., 2003). It is critical to understand the degree to which stimulus specificity determines response recovery to better understand how the variety effect stimulates eating. For example, if a child habituates to plain tortilla chips, will they recover responding if salsa is now available? Likewise, if they habituate to cheese pizza, would they recover motivated responding if pepperoni pizza was now available?

The question of how much change in a food is necessary for stimulus specificity of food is central to understanding how food characteristics are related to the effects of food variety on habituation and energy intake. One theoretical approach that can be used to understand mechanisms for habituation is SOP, a network connectionist approach to memory (Wagner, 1981) in which short-term memory is represented by activity in memory "nodes" embedded in an associative structure representing many nodes and their interconnections. A core principle of the SOP model is that presentation of a stimulus activates a memory node to a high state of activity (A1 state), which decays over time to a lower level of activity (A2 state), and then becomes inactive (I state). When a node is in the A1 state, it is maximally active. In contrast, when it is in the A2 state, the processing is more peripheral. The flow of information is unidirectional from A1 to A2 to I. In theory (Epstein, Temple, et al., 2009) at the onset of the first habituating stimulus, the node representing the first habituating stimulus becomes activated to the A1 state and then quickly decays to the A2 state. If the memory node for the stimulus is in the A2 state, presentation of the same stimulus would prevent this stimulus from commanding full behavioral potential because activation cannot go from A2 to A1. Presentation of a new stimulus activates its own, new, node to the A1 state. In the stimulus specificity paradigm, presentation of a novel food stimulus activates its own new node to A1. Responding will be high to the new stimulus (and appear to recover) because only the memory node associated with the first stimulus has shifted to the A2 state.

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A critical question to understand recovery of responding and the variety effect is what constitutes a novel food stimulus that would activate a new memory node (A1) and reinvigorate responding? In the present study, all children habituate to elbow macaroni and cheese, and some children were given more of the same stimulus, while other children were given spiral macaroni and cheese, or chicken nuggets. While chicken nuggets are a very different food from elbow macaroni and cheese, spiral macaroni and cheese shares most characteristics with elbow macaroni and cheese, including the same ingredients for the pasta and the sauce, with identical macronutrient profiles. However, the two forms of macaroni and cheese are different visually, in texture and may hold sauce differently. Thus, this design provides a strong test of stimulus specificity since the two foods share many common elements in comparison to chicken nuggets.

A secondary aim is to assess the relationship between sensitization and response recovery in a stimulus specificity paradigm. Food may have motivational as well as sensory properties. The dual nature of motivationally charged stimuli to activate an emotive node corresponding to the motivational properties of food, as well as activating a sensory node, which is in part the basis for habituation, has been recognized in AESOP, an affective extension of the SOP model (Wagner & Brandon, 1989). Both motivational and sensory nodes are activated to A1, A2, and then become inactive again, but the emotional responses unfold more slowly than the sensory responses over time. A crucial feature of the emotive node activated to A2 is that it invigorates behavior that is otherwise initiated. Thus, food can excite both "preparatory" (motivational) and "consummatory" behaviors (Konorski, 1967). As habituation to food is occurring within the meal (following the short-term dynamics of the consummatory node), the motivational node is exciting appetite and invigorating consumption behavior. Sensitization at the beginning of a meal may result from the parallel activation of motivational and consummatory nodes, as the first few bites of a food will excite both a motivational and a consummatory node. Since the motivational node decays more slowly over time, the longer term motivational activation activated by the next presentation of food may invigorate consummatory responding, followed by habituation. The dynamics of habituation of the consummatory node will tend to override the motivational node as the invigorating tendency would rapidly decline as the behavior elicited by the consummatory node habituates. We have previously observed that subjects who sensitize, or increase responding, before habituating had a slower rate of habituation and consumed more energy than those who did not sensitize (Epstein et al., 2008; Epstein, Robinson, et al., 2009). This study provides a test of whether individual differences in sensitization are related to recovery of responding when a new food is presented.

## Methods

### *Participants*

Participants were 35 female and 29 male 8–12-year-old children recruited from flyers and an existing database. Exclusionary criteria included: taking medications that might affect appetite (e.g. methylphenidate), medical or psychological conditions that might affect eating (eating disorders, upper respiratory illness, diabetes), current developmental disability or psychological disorder, or allergies or unwillingness to eat the foods in the study.

### *Procedures*

Parents of participants were screened by telephone and eligible participants were scheduled for one 60–90 min visit on a weekday between the hours of 2:30 and 5:30 p.m. Children were stratified by overweight ($\geq$85th BMI percentile) status and gender, and randomized into one of three groups: SAME food, SIMILAR food, DIFFERENT food. Parents were instructed to have their children eat their normal breakfast and lunch, but to not eat or drink anything (except water) 3 h prior and not consume study foods 24 h prior to the visit. Upon arrival at the laboratory parents and children completed consent and assent forms along with a child same-day food recall. Parents completed a demographic form while the child completed food liking, hunger and food preference questionnaires. Parents were escorted to the waiting area and the experimental task commenced. After the experimental task, participants filled out a hunger scale and a Dutch Eating Behavior Questionnaire adapted for children (Hill & Pallin, 1998) which assesses dietary awareness. Height and weight were then obtained. Finally, parent and child were debriefed and given written materials about the rationale behind the experiment. Participants were compensated with a $20 gift card for completing the experiment and parents were compensated with a $10 gift card for travel and/or child care expenses. All procedures were conducted in accordance with guidelines for the ethical conduct of human research outlined by the National Institutes of Health and with the approval of the University at Buffalo Children and Youth Institutional Review Board.

### *Laboratory environment*

The eating behavior laboratory is equipped with an air delivery system that circulates new air through each room approximately 10 times/h. The experiment rooms were interfaced with intercom systems so the participant could communicate with the experimenter in an adjacent control room throughout the experiment.

### *Measures*

#### *Habituation of responding*

Responding on a computer controlled variable interval 120 s (VI-120) reinforcement schedule was used to measure instrumental responding for food. The task consisted of two squares, one that flashed red every time a mouse button press occurred and another square that flashed green when a point was earned after the VI interval had timed out. Participants were reinforced with a 100 kcal portion of food for the first response made after approximately 120 s had passed. The task, consisting of habituation and recovery phases, was presented for 28 min, which provided the opportunity for each child to earn up to 14 portions of food if they maintained responding. At the beginning of the task participants were instructed that when they no longer wanted to earn access to food they could go to another table and engage in the alternative activities, which included age appropriate puzzles, crosswords, word searches, and magazines. Participants were told that they could move freely between the computer and activity stations.

The task was divided into habituation and recovery phases. The habituation phase lasted 24 min during which participants earned access to 100 kcal portions of Kraft® Elbow Macaroni and Cheese. The recovery phase lasted for 4 min, and the phase began with a new VI 120 s schedule, during which participants had the opportunity to earn 100 kcal portions of either Kraft® Elbow Macaroni and Cheese (SAME food group), Kraft® Spiral Macaroni and Cheese (SIMILAR food group), or Chicken nuggets (DIFFERENT food group). The experimenter entered the room between the habituation and recovery phases to show the participant a sample bowl of food that they would be working for during the recovery phase.

The energy density of Kraft® Macaroni and Cheese, Kraft® Spiral Macaroni and Cheese (both prepared using the classic recipe), and chicken nuggets were 2.08, 2.08 and 3.21 kcal/g.

Participants received the food immediately after each point was earned and could continue to work on the habituation task while eating. The energy intake of the food was determined by weighing the foods before and after the task to the nearest 1 g, and estimating energy based on the energy density of the food. Water was provided *ad libitum* throughout the duration of the experiment. The primary outcome measures were the number of responses made for food during each 2-min interval and the amount of food (g) and energy (kcal) consumed.

Experimenters wore latex gloves for all food handling and maintained careful laboratory hygiene throughout the experiment. Experimenters heated frozen chicken nuggets in a convection oven, wrapping each 100 kcal portion in aluminum foil when cooking was completed, and placing them back in the convection oven at 175 °C to maintain a constant temperature. A batch of macaroni and cheese was prepared, with individual portions placed in covered bowls. Prior to presentation to the subject each portion of macaroni and cheese was microwaved for 10 s to standardize temperature. Specifics of the food preparation were extensively pretested to provide the most appealing foods that participants would be motivated to eat.

*Food hedonics and hunger*

Liking of study foods was assessed by 5-point Likert-type scales, anchored by one "Do not like" and by five "Like very much". Hunger/fullness was measured at the beginning and end of each session, and assessed on a 5-point Likert-type scale, anchored by one "Extremely hungry" and by five "Extremely full".

*Same-day food recall*

Same-day food recalls were conducted by interview with both the child and parent present. This measure was to verify adherence to the protocol by ensuring the participant did not report consumption of food or drink (except water) in the 2 h prior to the appointment and that they had not consumed the study foods in 24 h.

*Demographics*

A general demographics questionnaire was used to assess education status, annual income, race and ethnicity.

*Anthropometrics*

Height (cm) and weight (kg) were measured without shoes and in light clothing using a Digi-Kit™ digital stadiometer (North Bend, WA) and a Tanita™ digital weight scale (Arlington Heights, IL) after the participant had voided. These measurements were used to calculate BMI (kg/m$^2$). Children below the 85th BMI percentile were defined as non-overweight while children greater than or equal to the 85th BMI percentile were defined as overweight (Barlow, 2007; Kuczmarski et al., 2000).

*Dietary awareness*

The Dutch Eating Behavior Questionnaire revised for children ages 8–12 was utilized to measure dietary awareness (Hill & Pallin, 1998). Examples of questions asked on the DEBQ are "I have tried to lose weight"; "I try not to eat between meals because I want to be thinner". The median score on this questionnaire was 6.

*Analytic plan*

Participant characteristics were compared between the three experimental groups using one-way analysis of variance or Chi-square for categorical variables.

Changes in motivated responding (mouse button presses) to obtain food across 2-min time blocks were analyzed using mixed analysis of covariance, with groups (SAME, SIMILAR, DIFFERENT) as the between variable, and 2-min time blocks as the within variable. The data were analyzed separately for the habituation (2 min blocks 1–12) and recovery (2 min blocks 12–14) phases, as well as in one larger analysis. Analysis for the recovery phase included time blocks 12–14 to assess changes in responding from the last habituation trial. The results of the two analyses were similar, and the separate analyses are presented to facilitate interpretation of the data. Covariates for the analysis of variance include measures that were different by group, which was the liking for the foods presented during the recovery phase. Greenhouse–Geiser corrected *F* values were used to correct for sphericity in repeated measures. Differences in volume of food consumed and energy intake were assessed using one-way analysis of covariance, with food group as the between group factor and liking of the recovery food as the covariate. Contrasts were used to test between group differences in change over time. To be conservative, the probability for significance for the three food contrasts was adjusted by 0.05/3 = 0.0133. Analyses were also completed with overweight status as a between subject variable to test whether overweight status differentially influenced recovery of responding for food as a function of stimulus specificity.

Sensitization was defined similarly to our previous research (Epstein et al., 2008; Epstein, Robinson, et al., 2009), as a 10% increase in responding in a subsequent time block above responding during the first 2 min time block. In these studies we showed that this definition improved the fit of the regression model predicting responding more than definitions of sensitization of a 10% increase in responding for the first 4 min, or a 20% increase for either the first 2 or 4 min time blocks, as well as maximizing the number of subjects who met the criteria for sensitization (Epstein et al., 2008; Epstein, Robinson, et al., 2009). Fourteen subjects met this definition of sensitization. *T*-Tests and Chi-square tests were used to assess subject differences for those who did or did not sensitize. The effect of sensitization on responding during habituation and recovery phases and on food and energy consumption was tested using similar analysis of covariance methods used to test the effects of food conditions, with age and dietary awareness as covariates. The data were analyzed separately for the habituation (2 min blocks 1–12) and recovery (2 min blocks 12–14) phases, as well as in one larger analysis. Analysis for the recovery phase included trial 12 to assess changes in responding from the last habituation trial.

## Results

*Participant characteristics*

The average participant was 10.5 ± 1.6 (mean ± SD) years of age and had a zBMI of 0.79 ± 1.08 (Table 1). The majority of the families had a household income of greater than $50,000 per year (68.8%). There were no differences ($p > 0.05$) between children in the groups for any characteristic except for food liking ($p < 0.05$), as the children in chicken nuggets group liked the recovery food more than children in the spiral macaroni and cheese group ($p = 0.014$). No differences in liking for elbow versus spiral macaroni and cheese were observed.

*Habituation*

The ANCOVA for responding, controlling for liking of the recovery foods, showed no significant differences by recovery food group during the habituation time blocks when all subjects worked for elbow macaroni and cheese ($F(22,627) = 1.13$, $p > 0.05$, effect size ($ES^F$) = 0.180), but the recovery food did influence responding during the recovery period ($F(4,114) = 3.46$, $p < 0.01$, $ES^F = 0.269$) (Fig. 1). Contrasts showed that children in the SIMILAR ($F(1,57) = 6.54$, $p < 0.0133$, $ES^F = 0.185$) and DIFFERENT

**Table 1**
Participant baseline characteristics by food characteristic.

| Characteristics | SAME, *N* | SIMILAR, *N* | DIFFERENT, *N* | Total, *N* |
|---|---|---|---|---|
| Total | 22 | 22 | 20 | 64 |
| Gender | | | | |
| *n* (%male) | 9 (40.9) | 12 (54.5) | 8 (40.0) | 29 (45.3) |
| Minority | | | | |
| *n* (%minority) | 7 (31.8) | 5 (22.7) | 4 (20.0) | 16 (25.0) |
| Income | | | | |
| Under $50,000 | 9 (40.9) | 6 (27.3) | 5 (25.0) | 20 (31.3) |
| $50,000–89,999 | 8 (36.4) | 8 (36.4) | 6 (30.0) | 22 (34.4) |
| Over $90,000 | 5 (22.7) | 8 (36.4) | 9 (45.0) | 22 (34.4) |
| Age | 10.6 ± 1.6 | 10.5 ± 1.5 | 10.3 ± 1.7 | 10.5 ± 1.6 |
| zBMI | 0.7 ± 1.0 | 0.7 ± 1.2 | 0.9 ± 1.0 | 0.8 ± 1.1 |
| Liking for macaroni and cheese | 4.3 ± 0.8 | 4.4 ± 0.7 | 4.3 ± 0.9 | 4.3 ± 0.8 |
| Liking for recovery food | 4.2 ± 0.8 | 3.9 ± 1.4 | 4.7 ± 0.7 | 4.2 ± 1.0* |
| Hunger | 2.6 ± 0.7 | 2.3 ± 0.7 | 2.5 ± 0.9 | 2.5 ± 0.8 |
| Dietary awareness | 5.0 ± 2.9 | 5.1 ± 2.5 | 5.7 ± 2.9 | 5.3 ± 2.7 |

*Note*. Dietary awareness was measured using the Dutch Eating Behavior Questionnaire, hunger/fullness and liking were measured using 5-point Likert-type scales, with 1 being hungry or low in liking, 5 full or high in liking, BMI = body mass index (kg/m$^2$).
* $p < 0.05$ between groups.

($F(1,57) = 6.99$, $p = 0.01$, $ES^F = 0.191$) groups responded more for macaroni and cheese than children in the SAME group, but no differences in responding for food in the SIMILAR and DIFFERENT groups were observed ($F(1,57) = 0.01$, $p = 0.91$, $ES^F = 0.009$). Analysis of subjects in the SAME group showed that they significantly increased their responding from the last trial block in habituation to the trials blocks after the new instructions were presented to subjects ($F(1,57) = 5.68$, $p = 0.021$, $ES^F = 0.172$). No differences in amount ($F(2,57) = 0.97$, $p > 0.05$, $ES^F = 0.123$) or energy of food consumed ($F(2,57) = 0.97$, $p > 0.05$, $ES^F = 0.123$) were observed during habituation, but groups differed in the amount of food consumed ($F(2,57) = 9.84$, $p = 0.0002$, $ES^F = 0.392$), and energy intake ($F(2,57) = 16.79$, $p < 0.0001$, $ES^F = 0.512$) during the recovery period. Subjects consumed more food in the SIMILAR ($F(1,57) = 17.13$, $p = 0.0001$, $ES^F = 0.366$) and DIFFERENT ($F(1,57) = 11.12$, $p = 0.0012$, $ES^F = 0.295$) conditions (left graph, Fig. 2) in comparison to the SAME condition, but no significant differences were observed for the SIMILAR versus DIFFERENT groups ($F(1,57) = 0.52$, $p > 0.05$, $ES^F = 0.064$). Subjects consumed more energy in the SIMILAR versus SAME ($F(1,57) = 13.77$, $p = 0.0005$, $ES^F = 0.328$) and DIFFERENT versus SAME ($F(1,57) = 32.07$, $p < 0.0001$, $ES^F = 0.501$) conditions, but no significant differences were observed in the comparison of energy intake for the SIMILAR versus DIFFERENT conditions ($F(1,57) = 3.79$, $p > 0.05$, $ES^F = 0.172$) (right graph, Fig. 2). Overweight status did not interact with foods to influence recovery of responding.

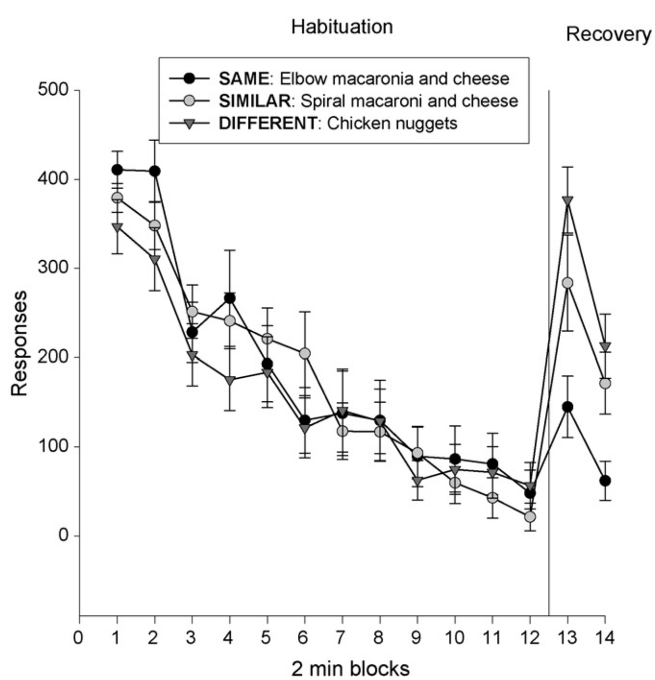


**Fig. 1.** Motivated responding over time for variable interval 120 s schedules of reinforcement for SAME ($n = 22$), SIMILAR ($n = 22$) and DIFFERENT ($n = 20$) groups (mean ± SEM). ANCOVA showed differences in responding by groups during the recovery period ($p < 0.015$), and contrasts showed that the SIMILAR ($p < 0.0133$) and DIFFERENT ($p = 0.011$) groups responded more for food than the SAME group.

### *Sensitization*

Comparison of subjects who sensitized ($N = 14$) versus those who did not sensitize ($N = 50$) showed they were different for age and dietary awareness. Subjects who sensitized were older (11.3 ± 1.1 versus 10.2 ± 1.6, $p = 0.009$) and had greater dietary awareness (6.4 ± 2.2 versus 4.9 ± 2.8, $p < 0.05$). The ANCOVA for sensitization, controlling for age and dietary awareness, showed significant differences during the habituation time blocks when all subjects worked for elbow macaroni and cheese ($F(11,660) = 2.49$, $p = 0.025$, $ES^F = 0.189$), but subjects did not differ in response to the recovery food ($F(2,120) = 1.65$, $p > 0.05$, $ES^F = 0.131$) (Fig. 3). Subjects who sensitized differed in the amount of food they ate ($F(1,60) = 6.28$, $p = 0.015$, $ES^F = 0.313$) (left graph, Fig. 4) and energy consumed during the habituation phase ($F(1,60) = 6.28$, $p = 0.015$, $ES^F = 0.313$) (right graph, Fig. 4). No differences in amount ($F(1,60) = 1.12$, $p > 0.05$, $ES^F = 0.132$) or energy of food consumed ($F(1,60) = 1.31$, $p > 0.05$, $ES^F = 0.142$) were observed during recovery in relation to sensitization.

## Discussion

The results show strong stimulus specificity determining recovery of motivation for food. While it was expected that providing chicken nuggets would result in recovery of the motivation to eat, recovery of responding was also observed for spiral macaroni and cheese. From a nutritional perspective these are identical foods, based on the same pasta but in different shapes,

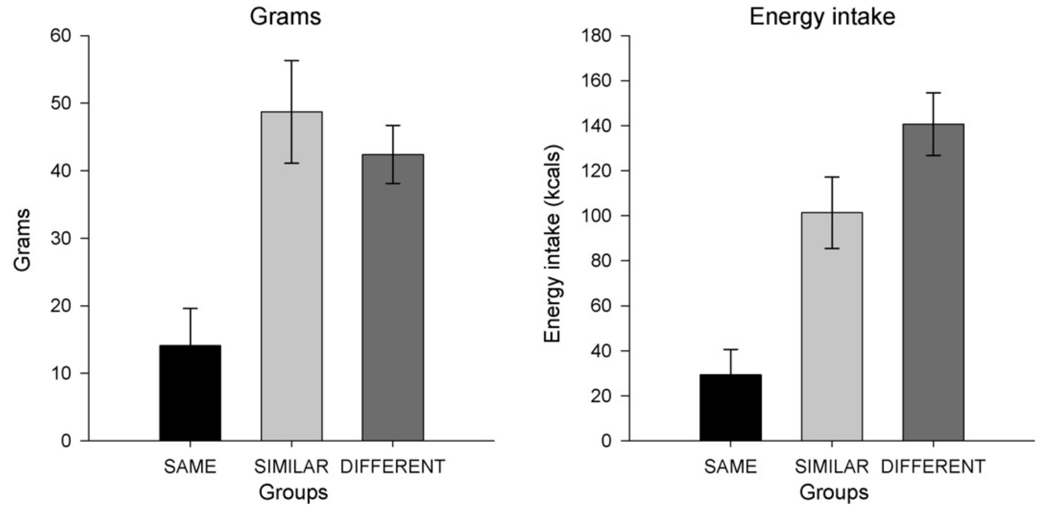


**Fig. 2.** Volume of food consumed (left graph) and energy consumption (right graph, mean ± SEM) during the recovery phase for children in the SAME ($n$ = 22), SIMILAR ($n$ = 22) and DIFFERENT ($n$ = 20) groups. ANCOVA showed significant differences in volume of food consumed ($p$ = 0.0002) and energy intake by group ($p < 0.001$), with greater volume of food consumed ($p$'s $< 0.002$) and greater energy intake ($p$'s $< 0.001$) for children in the SIMILAR and DIFFERENT groups responded more for food than the SAME group.

prepared using the same basic recipe, with the same energy density. There are stimulus differences between the foods, as they look different, have a different texture due to the different shapes and a different mouthfeel, and may hold the cheese sauce differently than elbow macaroni and cheese. There were no differences in liking between elbow and spiral macaroni and cheese, which highlights the extent to which stimulus specificity may drive the motivation to eat. Children did report liking chicken nuggets more than spiral macaroni and cheese, but recovery was observed for both types of foods. While it is well known that food variety increases energy intake, the characteristics of the foods that have been studied are usually very different. This study is the first to assess how small differences in the characteristics of foods can influence recovery of responding of the motivation to eat after habituation. No differences in responding to the different types of foods were observed for overweight or non-overweight youth, which suggests that recovery of responding when a novel food is presented after habituation can be generalized to all children, independent of overweight status. The effects of weight status may

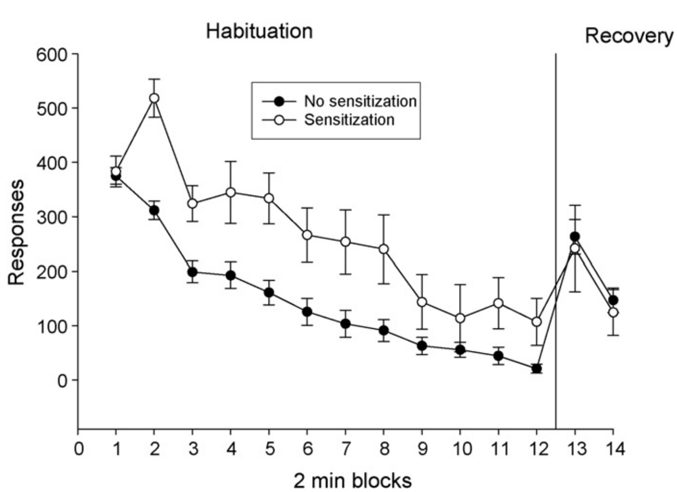


**Fig. 3.** Motivated responding (mean ± SEM) on variable interval 120 s schedules of reinforcement for children who sensitized ($n$ = 14) and those who did not sensitize ($n$ = 50) using the definition of an increase in responding of at least 10% for minutes 3 and 4 compared to minutes 1 and 2. ANCOVA showed a significant difference in the rate of habituation comparing those who sensitized versus those who did not sensitize ($p$ = 0.025).

be different for habituation to a variety of foods, as we have shown overweight children consume more food when presented with a variety of foods during habituation than non-overweight children (Epstein, Robinson, et al., 2009).

It is interesting that all subjects showed recovery from 2 min blocks 12–14, including subjects who received the same food on 2 min blocks 13 and 14. This is likely due to the fact that after trial 12 the experimenters entered the room to deliver new instructions to all subjects, which may have served as a dishabituator, such subjects increased their responding for the same food. Thus, it may be that the increased responding for the spiral macaroni and cheese and chicken nuggets was due to a combination of the dishabituating effects of receiving new instructions plus receiving new types of foods.

While differences in the characteristics of foods is relevant to understanding nutritional aspects of eating, the important point from the perspective of SOP, the connectionist memory model that we use to conceptualize habituation (Wagner, 1981) is whether the presentation of the new foods activate new memory nodes, that lead to more responding. If new memory nodes are activated, then recovery of responding should occur. While there are many similarities between elbow and spiral macaroni and cheese, there are enough differences to stimulate activation of a new memory node when a new food is experienced. If this small difference is enough to produce activation of a memory node and recovery of responding, then it is likely that bigger differences between foods, such as adding pepperoni to pizza, or cheese to a hamburger, could activate the motivation to eat in someone who has habituated to the former food.

Habituation may be one mechanism for the positive effect of food variety on energy intake (Epstein, Temple, et al., 2009), and research on stimulus specificity may provide ideas for what types of variations in foods might lead to increases in energy intake. Many studies of variety examine large distinctions between foods and food groups, usually based on food frequency questionnaires (McCrory et al., 1999; Raynor, Jeffery, Phelan, Hill, & Wing, 2005; Sea, Woo, Tong, Chow, & Chan, 2004). This research has been invaluable in demonstrating that a large variety of less healthy foods coupled with a reduced variety of healthier foods is associated with increased body weight. Despite the utility of questionnaires to demonstrate the basic variety effect, these measurements are not sensitive to the types of differences between foods that are critical to regulating food volume and

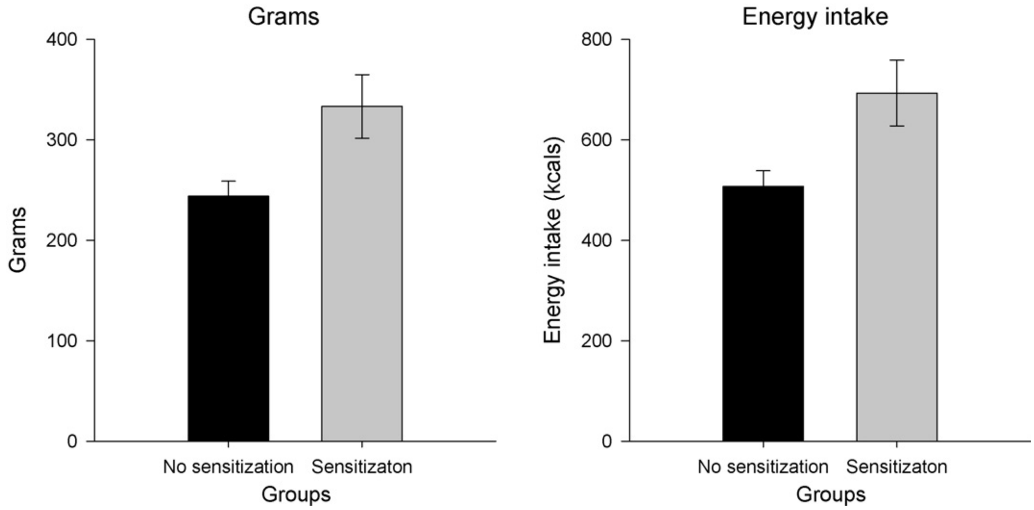


**Fig. 4.** Volume of food consumed (left graph) and energy consumption (right graph, mean ± SEM) for children who sensitized ($n$ = 14) versus did not sensitize ($n$ = 50). ANCOVA showed significant differences in volume of food consumed ($p$ = 0.015) and energy intake ($p$ = 0.015) for those who sensitized versus did not sensitize during the initial habituation trials.

energy intake. This study points to the need for more detailed recording to understand the role of food variety on energy intake. The effect of variety may be more powerful than expected if small difference in the characteristics of foods prolong eating episodes.

One question raised by this study is whether small variations in healthier foods would also result in more eating of healthy foods. We have demonstrated in previous research that increasing the variety of healthier foods will also increase the motivation to eat (Temple et al., 2008), but that study used different foods, and did not test the stimulus specificity of similar foods, such as different types of apples, or carrots with and without yogurt dip, etc. It is important to test whether the effects of variety on intake can be generalized to healthy foods.

This study replicates previous studies that show children who sensitize responding prior to habituation have a slower rate of habituation and consume more food and energy than those who only habituate (Epstein et al., 2008; Epstein, Robinson, et al., 2009). Sensitization, just as habituation, can also be understood using associative conditioning models. Food can excite both "preparatory" (motivational) and "consummatory" behaviors (Konorski, 1967), and the increase in responding for food for some people may be an example of motivational activation. This is consistent with research showing presence of a CS or situation associated with food will also excite and initiate feeding behavior (Johnson, McPhee, & Birch, 1991; Weingarten, 1983, 1984; Woods & Strubbe, 1991), and Swithers has shown that the sensitization component of the habituation curve is mediated by dopaminergic activity (Swithers, 1996). Even as food may activate motivation for some people, habituation to that food should also proceed, and the pattern of responding may best be predicted by the balance of the activation of motivational and consummatory processes (Epstein, Temple, et al., 2009). The first effect will tend to invigorate consummatory responding, whereas the second one will tend to decrease it. Activation of the motivational node cannot invigorate food consumption if the consummatory node fails to reach A1, and the dynamics of habituation of the consummatory node will tend to override the consequences of motivational conditioning and responding. Thus, although the motivating effects of encountering a situation previously associated with food might well enhance consumption at the start of a meal, this invigorating tendency would rapidly decline as the behavior elicited by the consummatory node habituates (Epstein, Temple, et al., 2009). The effects of sensitization did not differ for overweight or non-overweight children, suggesting this may represent a basic process relevant to eating of lean and overweight children.

Habituation is often assessed for reflexive, physiological responses, such as electrophysiology or salivation. In a series of theoretical and conceptual papers, McSweeney and colleagues have argued that motivated behavior, or behavior that is engaged in to gain access to reinforcers such as food, habituates (McSweeney et al., 1996; McSweeney & Swindell, 1999b). In operant conditioning studies with rats and pigeons, high levels of responding for food are observed in the initial trials in a session, followed by a decrease in responding over repeated trials (McSweeney, Murphy, & Kowal, 2001; McSweeney & Swindell, 1999a), and in humans a reduced motivated responding for food recovers after presentation of new food (Epstein et al., 2003). These observations are consistent with habituation and, thus, satiation for food may be due, in part, to "reinforcer habituation". This provides support for the theory that decreases and recovery of motivated responding and habituation of physiological responses that are related to eating are regulated by common mechanisms.

This study has focused on the use of the stimulus specificity paradigm and habituation theory to understand how small differences in the characteristics of food can influence intake. Research using the sensory specific satiety paradigm has also shown that small differences in the characteristics of the food, such as differences in the shapes of pasta (Rolls, Rowe, & Rolls, 1982) are enough to influence rate of change in pleasantness of the food and the amount of food consumed. The sensory specific satiety paradigm can assess how the characteristics of food, rather then energy depletion, can influence eating. In this paradigm liking ratings for multiple foods are obtained, a food is eaten to satiation, and ratings of foods are again obtained, with the expectation that the liking ratings will decrease more for foods that are consumed than foods that are not consumed. We have discussed similarities and differences and overlap between the habituation and sensory specific satiety paradigms, with the suggestion that the sensory specific satiety paradigm represents an example of the more general phenomenon of habituation.

This research utilizes habituation theory to better understand how differences in food can activate responding and lead to the effects of food variety on eating. Additional research is needed to replicate and extend characteristics of food that may lead to changes in motivation to eat, as well as a better understanding of mechanisms for this effect. This theoretical approach is unique in using a memory based model to understand factors that influence the motivation to eat, which expands the theoretical approaches that may provide new insight into factors that influence habituation of the motivation to eat.

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