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Dietary Variety Impairs Habituation in Children

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Abstract

Objective—The purpose of these studies was to test the hypothesis that dietary variety decreases the rate of habituation and increases energy intake in children.

Design—In Experiment 1, salivation in response to the same or a variety of food cues was measured followed by consumption of the study food(s). In Experiment 2, children responded in a computer task to earn points for the same or a variety of low or high energy density foods, which were then consumed.

Main Outcome Measures—Salivation, number of responses, and energy intake were measured.

Results—Participants in the same groups habituated faster than those in the variety groups ($p < .05$), and in Experiment 2, the effect of variety was independent of energy density. Participants in the variety groups also consumed more energy than those in the same groups in both experiments ($p < .05$).

Conclusions—Dietary variety disrupted habituation and increased energy intake in children. In addition, the response to dietary variety was independent of energy density, suggesting that increasing variety of low energy density foods may increase consumption.

Keywords

dietary variety; obesity; ingestive behavior; sensory specific satiety; energy density

Habituation is a ubiquitous characteristic of the nervous system that has been used to understand behavioral and physiological responding for food (Epstein, Rodefer, Wisniewski, & Caggiula, 1992; Groves & Thompson, 1970; Romero & Polich, 1996). Repeated exposure to the same food stimulus leads to decreased responding (Groves & Thompson, 1970), and exposure to a novel stimulus will restore responding to the novel and the previously habituated stimulus (Epstein, Rodeter, et al., 1992; Swithers, 1995; Swithers & Martinson, 1998; Swithers-Mulvey, Miller, & Hall, 1991; Wisniewski, Epstein, & Caggiula, 1992). Slower habituation and greater recovery is associated with increased energy consumption (Wisniewski et al., 1992). Thus, exposure to a variety of foods during a meal may slow down the rate of habituation and, in turn, increase energy consumption (Epstein & Paluch, 1997; Myers Ernst & Epstein, 2002).

A consistent body of research has shown that people consume more energy when given a variety of food than when given the same food (Clifton, Burton, & Sharp, 1987; Raynor & Epstein, 2001; Rolls et al., 1981; Rolls, van Duijvenvoorde, & Rolls, 1984) even when the source of

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the variety is small, such as different shaped pasta or different flavors of yogurt (Rolls & McDermott, 1991; Rolls, Rowe, & Rolls, 1982). This propensity to ingest a variety of foods is an evolutionarily advantageous phenomenon that may ensure a balanced nutrient intake (Raynor & Epstein, 2001). However, in the current obesogenic environment, dietary variety may be contributing to the growing obesity epidemic (McCrory et al., 1999; Raynor & Epstein, 2001; Raynor, Jeffery, Tate, & Wing, 2004). Consumption of a variety of high energy density (HED) foods coupled with low intake of fruits and vegetables and a lack of physical activity leads to maintenance of positive energy balance and, eventually, obesity (McCrory et al., 1999; Raynor & Epstein, 2001). McCrory and colleagues (1999) reported that there was a positive relationship between body mass index (BMI) and variety of sweets, snacks, carbohydrates, entrees, and condiments consumed, and a negative relationship between BMI and consumption of a variety of vegetables (excluding potatoes) in weight-stable adults who accurately reported food intake for 6 months. Likewise, those who lost the most weight and maintained the greatest degree of weight loss in an obesity treatment program consumed the smallest variety of high fat foods, oils, and sweets and the largest variety of low fat breads and vegetables (Raynor et al., 2004).

Another potential contributor to the current obesogenic environment is energy density (ED), or the amount of energy per gram of food. In studies in which ED has been manipulated, consumption of HED foods increases energy intake and consumption of low energy density (LED) foods decreases energy intake, independent of macronutrient composition of meals and subjective hunger and fullness (Ello-Martin, Ledikwe, & Rolls, 2005). These effects not only occur in single meals, but persist for subsequent meals (Bell et al., 1998; Rolls, Roe, & Meengs, 2004). Because individuals, on average, consume a consistent weight of food and subsequently report equivalent levels of fullness, despite differences in ED, it may be possible to decrease total energy intake by increasing consumption of LED foods (Bell et al., 1998; Bell & Rolls, 2001). For example, Rolls and colleagues (2004) had participants consume “satisfying” portions of an LED food as a first course to an ad libitum pasta meal, which reduced total energy intake and energy intake of the main course when compared to a group that had no first course, despite the fact that self-reported hunger and fullness were equivalent among the groups. These studies suggest that a useful strategy to decrease energy intake among overweight individuals may be to encourage consumption of large portions of LED foods in an effort to reduce consumption of HED foods, and thus decrease total energy intake.

Epidemiological research also shows that energy density may influence body weight. Participants with the highest level of fruit and vegetable consumption, had the lowest ED intakes and were the least likely to be obese (Ledikwe et al., 2006). However, other investigators question how much ED contributes to obesity (Gatenby, Aaron, Morton, & Mela, 1995; Heini & Weinsier, 1997). The food industry has been working to develop lower ED versions of highly liked foods that are equally palatable. Despite their commercial success, the increased availability and consumption of low fat (and thus lower ED) snack foods has not led to any significant reductions in average body weight (Stubbs, Ferres, & Horgan, 2000). In fact, within the United States, widespread reductions in dietary fat intake have corresponded to large increases in the incidence of obesity (Willett, 2002). Thus, changing ED in the diet by reducing the ED of high fat foods may not alter energy intake. Reduction in dietary fat is not the only way to reduce ED. Increased consumption of fruits and vegetables may be a healthier, more satisfying way to reduce overall energy intake (Rolls et al., 2004). It is, therefore, important to determine ways in which to increase fruit and vegetable consumption.

The purpose of the present experiments was to investigate the impact of dietary variety and ED on habituation to food in children. In Experiment 1, we examined habituation of salivary responses to olfactory cues from the same or a variety of HED foods. In Experiment 2, we repeated this study testing habituation of motivated responding for food. In addition, because

the variety effect depends on changes in the sensory characteristics of the foods, it should be independent of ED and, therefore, a variety of LED or HED foods should both decrease the rate of habituation and increase energy intake. To test this hypothesis, we measured motivated responding for the same or a variety of HED and LED foods. These experiments provide insight into factors that regulate food intake and extend our knowledge of the influence of dietary variety and ED on ingestive behavior to children.

Experiment 1

Method

Participants—Participants were nonoverweight 9- to 12-year-old children recruited from media advertisements and direct mailings. Exclusion criteria included presence of one or more of the following: taking medications or having medical conditions that may suppress appetite or alter responding to food cues (e.g., methylphenidate, Attention Deficit Hyperactivity Disorder, diabetes, upper respiratory illness); current psychological disorder or developmental disability; rating food stimuli < 3 on a 5-point Likert-type scale of liking; BMI percentile of > 95th, or abnormal olfactory function (testing described later). Eligibility was determined on a phone screen with the parent of the potential participant. If eligible, participants were scheduled for a single 60- to 90-minute visit to the laboratory between the hours of 2:00 to 5:00 p.m. Twenty U.S. dollars were given for completing the experiment. All procedures were approved by the University at Buffalo Health Sciences Institutional Review Board, and informed consent was obtained from parents and assent from children.

Design and Procedure—At scheduling, parents and children were informed that the participant was not to consume study foods within 24 hr of the experiment, and not to consume food or drink beverages (except water) at least 3 hr prior to the visit. Prior to the session, the participant selected his or her favorite food from a list of foods available in the experiment (hamburger, chicken nuggets, or french fries). On arrival at the laboratory parent and child completed consent and assent forms, and the parent filled out a demographics form and assisted with the child's same-day food recall to ensure compliance with the dietary instructions. The participant completed a 40-item food liking questionnaire, liking (example "How much do you like cheeseburger?") and wanting (example "How much do you want to eat a cheeseburger?") scales of the specific study foods, ranking of the study foods, and a hunger scale. Both hunger and wanting were assessed pre- and postexperiment. The participant also completed a Dutch Eating Behavior Questionnaire (Hill & Pallin, 1998) to measure dietary restraint.

The experimental session consisted of one baseline trial (an empty plate) and nine 1-minute salivation trials with food as the olfactory stimulus. Food stimuli were heated in the microwave for 25 s and positioned approximately three inches from the nose. After each salivation trial ended, the food stimulus was removed from the experimental room. Between the olfactory food trials there were 1-minute intertrial intervals in which participants listened to white noise (62 db). Participants were randomly assigned to either the Same or Variety group. The food trials consisted of either the participant's favorite food repeatedly presented for all nine trials (Same) or a variety of foods presented for the nine trials (Variety). All participants, regardless of condition, received a 40 ± 3 g (~100 Kcal) portion of their favorite food from among the following choices: Wendy's® Chicken Nuggets, Wendy's® French Fries, or Wendy's® Jr. Hamburger for the first salivation trial after baseline. After the first trial, participants in the Same group continued to receive their favorite food throughout the duration of the experiment. Participants in the Variety group were given one of four different foods on subsequent trials, with all four foods presented before any of the foods were repeated. For example, if the participant chose hamburger as their favorite food, they might receive hamburger on Trial 1, pizza on Trial 2, French fries on Trial 3, chicken nuggets on Trial 4, and hamburger on Trial 5. The order in which these foods were presented was counterbalanced.

Upon completion of the salivation trials, participants were given 1,000 Kcal portion of the study food(s) to consume ad libitum and height and weight were measured. Last, both parent and child were debriefed about the experiment, and olfactory function was measured.

Measurement

Salivation: Whole mouth parotid salivation was measured using The Strongin-Hinsie Peck (Peck, 1959) method. The participant was seated in a comfortable chair and instructed on cotton roll placement (cylindrical, 7 mm diameter, 38 mm length, Richmond Dental, Charlotte, NC), one cotton roll on both sides of mouth, between gum and cheek, and one underneath the tongue (Peck, 1959). During the salivation trials, participants wore headphones and listened to 62 dB white noise (i.e., to control for external auditory stimulation). While cotton rolls were in the mouth, the participant was instructed not to talk, swallow, chew or tongue cotton rolls. For practice, participant and experimenter both placed cotton rolls in mouth together and then the participant practiced by placing the cotton rolls in mouth without experimenter assistance. At the end of each trial, participants placed saturated cotton rolls in a plastic bag provided and the amount of salivation was calculated by taking the pre- and postweight of the cotton rolls and was weighed to 0.001 g on an Ohaus Precision Standard Scale (Florham Park, NJ). The change from baseline to each trial served as the primary outcome measure.

Olfactory function: Olfactory function was measured at the end of the experimental session by the Alcohol Sniff Test (Davidson, Freed, Healy, & Murphy, 1998), which has been validated for use in children. The participant was asked to smell a 70% isopropyl alcohol pad to familiarize the child with the scent and asked if he/she could detect an odor. The participant then stood with his/her back against the wall and closed his/her mouth and eyes while the experimenter placed a tape measure beginning even with the nose and extending toward the floor. The participant was instructed to report when the odor was perceived. Beginning at 300 mm below the nares, the alcohol pad was raised 10 mm with each aspiration. The distance at which the child first reported odor perception was recorded. A child with no deficit in olfactory function can detect the alcohol pad at distances between 200 to 250 mm. All children scored within this range.

Food hedonics: Liking of study foods was assessed by 5-point Likert-type scales ranging from 1 (*do not like*) to 5 (*like very much*). Wanting and hunger scales were designed similarly. A scale ranking the study foods was also implemented, “1” indicating the *most favorite* and “3 or 4” indicating the *least favorite* out of the foods presented. A 40-item Food Questionnaire within which the study foods were embedded was administered to ensure reliability of reported liking of foods presented. This questionnaire used a 5-point Likert-type scale ranging from 1 (*do not like*) to 5 (*like very much*).

Hunger and wanting of foods: Hunger and food wanting were assessed both before and after the experiment. Children were asked to indicate how hungry they were on a 5-point Likert-type scale ranging from 1 (*not hungry at all*) to 5 (*extremely hungry*). They were also asked to indicate how much they wanted to eat each of the study foods on a 5-point Likert-type scale ranging from 1 (*do not want at all*) to 5 (*want very much*).

Same-day food recall: Total energy consumption prior to the appointment was examined. This measure was used to ensure that the study foods were not consumed the day of the experiment and that the child adhered to not consuming food or drinking beverages except water at least 3 hr prior to scheduled appointment. With the parent present to assist in dietary recall, the child was asked to give details of the foods and beverages consumed that day, including times, amounts, and any added fat in the preparation. Energy consumption (kcal)

was calculated by Nutritionist V nutrient analysis software (First Data Bank; San Bruno, CA, 2000).

Dietary restraint: Dietary restraint was evaluated using the Dutch Eating Behavior Questionnaire designed and validated for use in children ages 8 to 12 (Hill & Pallin, 1998). A score greater than 7 on Questions 1 through 6 was considered dietary restrained. Examples of questions included on the restraint scale are “I have tried to lose weight” and “I try not to eat between meals because I want to be thinner”.

Demographics: The Hollingshead Demographics questionnaire (Hollingshead, 1975) was used to assess class, socioeconomic status, race, and ethnicity.

Anthropometrics: Height (cm) and weight (lbs) were measured using a SECA stadiometer (SECA, Hanover, MD) and balance beam weight scale that was calibrated daily. Both measures were used to calculate BMI (kg/m^2).

The Laboratory Environment

The laboratory is designed specifically for eating and smoking experiments and is constructed with a fresh air delivery system. The laboratory rooms have a negative pressure, so the exhaust (ft^3/min) is greater than the supply. The air circulates ~10 times/hour, or new air is circulated once every 6 min in the experimental room (1,385 ft^3). The experimental room is equipped with a Carbon HEPA Filtration System (Carbon, Permanganate, Zeolite) that filters at a rate of 225 ft^3/min to assist in removing airborne odorants. The design of the ventilation system coupled with the removal of the food stimuli immediately after the salivation trial has ended reduces the likelihood of lingering smells within the experimental room.

Analytical Plan

Between group differences in salivary responding from baseline across Trials 1 to 9 were measured with a repeated-measures analysis of covariance (ANCOVA), with group (Same, Variety) as the between-subjects factor and Trials (1 to 9) as the within-subjects factor. To examine potential influences of food choice on the rate of habituation, an ANCOVA was performed with favorite food as the between-subjects factor and Trials (1 to 9) as the within-subjects factor. In addition, the influence of favorite food on amount of food consumed and total energy intake were analyzed using ANCOVA with favorite food as the between subjects factor. Because of the established gender differences in food preferences and variety seeking (Cooke & Wardle, 2005; Nicklaus, Boggio, Chabanet, & Issanchou, 2005), gender was used as covariate in all analyses and baseline salivation was included as a covariate for analysis of salivary responses. Linear contrasts investigated the rate of change by group across trials. Between-group differences in energy consumption (kcal), amount of food consumed (grams), liking and wanting to eat each of the foods, and baseline and posttesting hunger were measured by ANCOVA with group (Same, Variety) as the between-subjects factor. Statistical analyses were conducted using SYSTAT Version 10.2 (Systat Software, 2002).

Results

Eighteen participants (8 male, 10 female) aged 9 to 12 were used for this study. The average participant was 11.2 ± 1.1 ($M \pm SD$) years of age with a body mass index ($\text{BMI} = \text{kg}/\text{m}^2$) of 19.6 ± 2.7 , and a BMI percentile of $68.2\% \pm 22.3$. Participants consumed an average of 907.3 ± 275.8 Kcal prior to their laboratory visit (see Table 1 for descriptive data by group). Youth were 83% non-Hispanic White, 6% Hispanics, and 11% African American, with socioeconomic levels of 50.1 ± 11.5 , corresponding to middle to upper class. There were no differences between the groups for baseline or posttesting hunger: baseline = $F(1, 15) = 1.92$,

$p = .19$; posttesting = $F(1, 15) = 0.914$, $p = .35$; liking of foods, hamburger = $F(1, 15) = 1.22$, $p = .28$, french fries = $F(1, 15) = 0.05$, $p = .84$; chicken nuggets = $F(1, 15) = 2.35$, $p = .15$; pizza = $F(1, 15) = 1.12$, $p = .31$; or wanting to eat foods, hamburger = $F(1, 15) = 2.46$, $p = .14$; french fries = $F(1, 15) = 0.44$, $p = .52$; chicken nuggets = $F(1, 15) = 0.04$, $p = .86$; pizza = $F(1, 15) = 1.67$, $p = .22$.

ANCOVA showed a significant Group $\times$ Time interaction for salivary habituation $F(8, 112) = 2.09$, $p = .04$; effect size (ES) = 0.32. Linear contrasts revealed that the Same group habituated significantly over the 9 trials $F(1, 14) = 12.19$, $p = .004$, but the Variety group did not $F(1, 14) = 0.001$, $p = .98$ (Figure 1A). In addition, in posttest consumption analyses, subjects in the Variety group consumed significantly more energy (36.9% more) $F(1, 15) = 5.24$, $p = .037$, ES = 1.11 (Figure 1B) as well as more grams of food (44.3% more) $F(1, 13) = 10.26$, $p = .007$, ES = 1.66 (Figure 1C) when compared to those in the Same group. One participant was eliminated from the intake analysis because he was an outlier (Kcal and grams of food consumption = > 2 SDs from the M consumption of that group). This had no effect on the outcome. Favorite food had no influence on rate of habituation $F(2, 14) = 1.33$, $p = .30$, the amount of food consumed $F(2, 14) = 0.21$, $p = .81$, or energy intake $F(2, 14) = 0.05$, $p = .95$.

Experiment 2

Results of Experiment 1 support the hypothesis that food variety slows the rate of habituation, which is related to greater energy intake than when the same food is presented repeatedly. Experiment 2 was designed to extend the analysis of the influence of variety on habituation of salivation to motivated behavior and to test the influence of ED on habituation.

Participants

Participants met the same criteria and were recruited using the same methodology as those used in Experiment 1.

Method

General procedures were similar to Experiment 1, with the exception that LED foods (peaches, pineapple, mandarin oranges, yogurt, baby carrots, fat free pudding, and grapes) were studied in addition to the HED food studied in Experiment 1, and children chose their favorite LED and HED foods from the lists of foods available in the experiment.

Participants were randomly assigned to the Same or Variety food conditions within the HED or LED conditions, which were run in separate cohorts. HED foods were the same as those used in Experiment 1 and all had an ED of > 2.3 kcal/g. All LED had an ED of < 1.0 kcal/g (Table 2). In Experiment 2, children worked for access to the food stimuli, and changes in rate of motivated behavior across presentation of the same or a variety of HED or LED foods were determined.

The participant's favorite food out of the four was presented for the first trial in both the Same and Variety conditions. Participants in the Variety condition never worked for access to the same food consecutively during the motivation task trials. In the HED food condition the foods used were the same as in Experiment 1, 40 ± 3 g portions of Wendy's® Junior Hamburger, Wendy's® Chicken Nuggets, Wendy's® French Fries (Wendy's; Columbus, OH), and Domino's® Cheese Pizza (Ann Arbor, MI). Food was wrapped in foil and kept warm at around 200° F in a convection oven. The LED foods included 40 ± 3 g portions of Dannon® Light n' Fit Yogurt (Minster, OH), Hunt's® Fat Free Pudding (ConAgra Foods; Mason, OH), baby carrots, grapes, Delmonte® Extra Light Syrup Peaches (San Francisco, CA), Dole® Mandarin Oranges served in light syrup, and Dole® Pineapple served in fruit juice (Westlake Village,

CA). The LED food stimuli were presented in paper bowls and kept refrigerated (4° C and 30% humidity).

Measurement

Food reinforcement task: A computer generated task was used to assess motivated responding for food. The reinforcement schedule was a variable ratio 100 (VR 100) with a range of $\pm 25\%$, that is, a point was earned after 75 to 125 button presses. This schedule of reinforcement remained the same throughout the duration of the testing session. The task consisted of two squares, one that flashed red every time a mouse button was pressed and another square that flashed green when a point was earned. The number of points earned per trial and a description with a picture of the food stimulus was presented on the computer monitor. The progression to the next trial would not occur until points were earned for the current trial. To receive the food stimulus, the participant had to earn a total of five points per trial. The game ended after 30 minutes, during which time children had the opportunity to play for 10 trials. Total number of responses per trial served as the primary outcome measure. After the participant earned five points the experimenter brought in the food for consumption. Water was also provided ad libitum throughout the experimental session. If the participant no longer wanted to earn points to eat food the child could engage in other activities (i.e., magazines, cross word puzzles, word finds) located at a table next to the computer station. This was to ensure that responding to the computer task was not out of boredom.

Analytical Plan

Between group differences in motivated responding were assessed using ANCOVA with group (Same, Variety) and energy density (HED, LED) as the between-subjects factors and Trials (1 to 10) as the within-subjects factor. Group differences in energy consumption (Kcal), amount of food consumed (grams), liking of study foods, and baseline and posttesting hunger were analyzed using ANCOVA. The influence of favorite food on the rate of responding was analyzed using an ANCOVA with favorite food as the between-subjects factor and Trials (1 to 10) as the within-subjects factor. In addition, the influence of favorite food on the amount of food and energy consumed was analyzed using ANCOVA with favorite food as the between-subjects factor. For the latter analyses, the HED groups and LED groups were analyzed separately. All analyses included sex, BMI percentile, and same-day energy intake as covariates.

Results

Participants were 18 males and 17 females, 10.8 ± 1.1 years of age with a BMI of 18.6 ± 2.1 , and a BMI percentile of $63.5\% \pm 21.4$. Participants were 83% non-Hispanic Whites, 3% Asian, 3% Native American, 8% African American, and 3% reported other for race, with a socioeconomic status of 46.7 ± 12.7 . Participants consumed an average of 637.6 ± 335.9 calories prior to visiting the laboratory (see Table 3 for descriptive data by group). There was a significant difference among the groups for BMI percentile $F(3, 33) = 3.10, p = .04$, and for total energy consumed that day prior to participating in the experiment $F(3, 33) = 4.50, p = .01$. There were no differences among the groups for baseline or posttesting hunger baseline = $F(3, 30) = 2.70, p = .06$ and post = $F(3, 30) = 1.39, p = .26$; liking of study foods, pizza = $F(1, 13) = 0.71, p = .42$; hamburger = $F(1, 13) = 0.71, p = .42$; french fries = $F(1, 13) = 0.04, p = .85$; chicken nuggets = $F(1, 13) = 2.4, p = .15$; pudding = $F(1, 14) = 0.67, p = .43$; yogurt = $F(1, 14) = 0.67, p = .43$; carrots = $F(1, 14) = 0.32, p = .58$; grapes = $F(1, 14) = 0.43, p = .53$; peaches = $F(1, 14) = 1.1, p = .30$; pineapple = $F(1, 14) = 0.002, p = .97$; mandarin oranges = $F(1, 14) = 1.49, p = .24$.

ANCOVA revealed a significant interaction between variety and trials. Participants in the Variety group maintained responding for significantly longer than those in the Same group F

(9, 297) = 2.35, $p = .04$, ES = 0.25 (Figure 2A), with no interaction of variety with HED/LED food status ($p > .05$). There were main effects of food variety $F(1, 30) = 11.67$, $p = .002$, ES = 0.65 and ED $F(1, 30) = 181.45$, $p < .0001$, ES = 2.12 on energy consumption as well as an interaction between these factors $F(1, 30) = 7.85$, $p = .009$, ES = 0.36 (Figure 2B). Post-hoc testing revealed that in participants receiving HED foods, variety significantly increased energy consumption, $F(1, 16) = 12.75$, $p = .003$, but in those receiving LED foods, there was no significant effect of food variety on energy consumption $F(1, 16) = 1.39$, $p = .256$. Participants in the LED and HED Variety groups consumed 45% and 46.9% more energy, respectively, than their Same food counterparts. There was a main effect of food variety on grams of food consumed ($F(1, 32) = 7.15$, $p = .012$, ES = 0.46), but no effect of ED and no interaction between the two (Figure 2C). Dietary variety increased the grams of food consumed by 32.1%. There was also no effect of favorite food on the rate of motivated responding ($F(90, 216) = 0.79$, $p = .90$). Nor did favorite food have any influence on the amount of food LED = $F(6, 12) = 0.25$, $p = .95$; HED = $F(3, 14) = 0.38$, $p = .77$ or energy consumed LED = $F(6, 12) = 0.30$, $p = .92$; HED = $F(3, 14) = 0.34$, $p = .80$, within each ED group.

Discussion

These studies demonstrate that dietary variety disrupts both salivary habituation and habituation of motivated responses to food stimuli in children. In Experiment 2, the effect of dietary variety on motivated responding occurred regardless of whether the child worked for LED or HED foods. Food variety increased energy consumption by an average of 42% in both studies (pos-texperimental energy intake in Experiment 1 and experimental energy intake in Experiment 2), relative to consumption by the Same food group. These studies provide support for the hypothesis that dietary variety increases food intake, and disruption of habituation may be an underlying mechanism for this effect.

Exposure to multiple foods can influence the rate of habituation. For example, studies in adults and children have shown that presentation of a novel food reinstates salivation (Epstein et al., 2003; Temple et al., 2006; Wisniewski et al., 1992) and motivated responding (Epstein et al., 2003; Temple et al., 2006) after habituation has occurred. Similarly, decreased rates of habituation are observed in adults working for access to a variety of foods as compared to a single food stimulus (Myers-Ernst & Epstein, 2002). The current findings demonstrate that, as in adults, children decrease the rate of habituation in response to food variety in tasks that measure physiological responses and motivated behavior. In addition, all of the studies mentioned above used HED foods. The current study extends these findings by showing that the decreased rate of habituation of motivated responding occurs when either LED or HED foods are used. These results are important because they suggest that responding to food variety is not dependent on ED, and increasing the variety of LED foods may increase consumption of LED foods and, therefore, reduce overall energy intake.

In addition to decreasing the rate of habituation, meal variety also increases energy intake, relative to a monotonous diet of the same types of foods (Raynor & Epstein, 2001). For example, participants receiving a four-course meal consisting of different foods in each course consumed 60% more energy than participants receiving the same food in each course (Rolls et al., 1984). Even when the variation in the food was more subtle, such as different flavored cream cheese in sandwiches, participants consumed more in the variety group than in the group receiving the same flavored sandwich (Rolls et al., 1982). Studies (Berry, Beatty, & Klesges, 1985; Pliner, Polivy, Herman, & Zakalusny, 1980; Spiegel & Stellar, 1990) have also investigated the influence of variety when all foods are served in a single course, and the same phenomenon is observed, even when the total ED presented is held constant. Given that exposure to a variety of HED foods both increases energy intake and decreases habituation, it is possible that the increased energy consumption observed during a high variety meal can be

attributed, in part, to slower rates of habituation. This theory is supported by the current study as well as previous research showing that individuals exhibiting slower rates of salivary habituation also consumed significantly more energy (Wisniewski et al., 1992).

In contrast to data on variety of HED foods, studies examining effects of increased variety of LED foods show many health benefits of this behavior, such as reduced weight and increased consumption of healthy foods. Increasing the variety of fruit and vegetable choices was related to increased fruit and vegetable consumption in elementary children (Adams, Pelletier, Zive, Sallis, 2005). In addition, we have previously shown better weight loss for obese adults who focus on increasing intake of healthy foods such as fruits and vegetables rather than focusing exclusively on reducing energy intake (Epstein et al., 2001). Finally, a prospective clinical trial examining the effects of increasing fruit and vegetable intake found that individuals who increased intake of LED foods had a 40% greater weight loss than those who were told to limit total energy intake (Ello-Martin et al., 2004).

Habituation theory may provide a different approach to energy regulation and body weight than usual weight control treatments. The current experiments focus on the influence of eating the same or a variety of foods during a single eating bout. The same principles may apply over multiple meals to influence long-term energy balance. It may be easier to regulate intake over time if people consumed the same foods in a regular pattern, rather continually varying foods that are available over meals. For example, eating the same breakfast every day may reduce energy intake over days in comparison to consuming different foods at each breakfast. Similarly, consuming foods in the same pattern each week, with the same Monday meal each week, and the same Tuesday meal each week, and so forth, may reduce motivation to eat more in comparison with varying each meal every day of the week. Because food variety may decrease sensory habituation and habituation of motivated responding for food, dietary approaches should reduce variety of HED foods to reduce energy intake. In addition, because increasing the variety of LED options inhibits habituation of motivation to obtain these foods, the variety of LED foods should be increased as variety of HED foods is reduced. Therefore, to capitalize on the natural tendency to seek out variety, a more successful treatment approach might be to recommend increasing variety of LED foods while decreasing variety of HED foods.

These results show that the influence of variety on habituation can be generalized across physiological and behavioral responses that regulate ingestive behavior. One of the major recent theoretical advances in habituation theory has been the demonstration that motivated behavior habituates, and changes in motivated behavior may be due in part to habituation (McSweeney, Hinson, & Cannon, 1996; McSweeney, Murphy, & Kowal, 2005; McSweeney & Swindell, 1999). We have shown that habituation of salivation and motivated behavior to food stimuli show a similar pattern and recover when a novel food stimulus is presented (Epstein et al., 2003; Temple et al., 2006). In addition, when habituation of salivation and motivated responding were measured within the same individuals, we showed that the rate of habituation of both of these responses was related (Temple et al., 2006). Therefore, it may be possible to reconceptualize such constructs as satiation in terms of reinforcer habituation (McSweeney & Roll, 1998; Temple et al., 2006). The extension of habituation theory to motivated behavior, which includes eating (McSweeney et al., 1996; McSweeney & Roll, 1998) as well as drug self-administration (McSweeney et al., 2005), may provide new insights into basic mechanisms that influence eating and energy regulation.

A methodological concern in Experiment 2 was that the participants randomly assigned to the Variety groups reported a greater same-day energy intake prior to coming to the laboratory than participants in the Same groups. There are two ways in which this could influence the results. It is possible that participants in the Variety group were less hungry because they had

consumed more food. However, we found no differences in self-reported hunger before or after the experiment. It is also possible that greater pre-experimental energy intake may predict increased motivation to work for food in the laboratory task. To control for that possibility, the amount of energy consumed prior to coming to the laboratory was introduced as a covariate in the analysis of habituation, with no change in the main pattern of results. Another methodological concern that participants in the Variety groups may have consumed less of the food as it was earned, which would have maintained motivation to eat. Experimenter observation showed that only two participants did not consume the food as it was presented, and both of these participants were in the Same, not the Variety group. Finally, although there were group differences in BMI percentile, controlling for BMI percentile had no effect on the experimental findings. All of the participants in this study were nonoverweight, and research has shown differences in the rate of habituation between overweight and nonoverweight children (Temple, Giacomelli, Roemmich, & Epstein, 2007), and adults (Epstein, Paluch, & Coleman, 1996).

Much of the previous work examining interactions between dietary variety and food intake has been conducted in adults. The purpose of this study was to extend that knowledge to children. Not only did we show that children are responsive to dietary variety, but we also showed that these individuals were equally responsive to HED and LED foods using a motivated responding paradigm. These studies provide important information about factors that regulate habituation and ingestive behavior in children. We have shown differences in the rate of habituation in lean and obese adults (Epstein et al., 1996), and it is possible that individual differences in sensitivity to food cues that slow down habituation may be a factor in the development of overweight in children. Future research is needed to establish whether individual differences in habituation to food cues at an early age predict excessive weight gain during childhood and adolescence that sets a trajectory for the development of pediatric and then adult obesity.

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Figure 1.

Dietary variety disrupts salivary habituation and increases caloric consumption. A. (Top graph) Mean $\pm$ SEM salivation (grams) over nine presentations of olfactory food stimuli in a group presented with the same food for all trials (closed circles) or a variety of foods (open circles). ANCOVA showed that a significant Group $\times$ Time interaction in rate of change in salivation ($p < .05$), with participants in the Same food group, but not the Variety food group, significantly habituating. B. (Middle graph) Mean $\pm$ SEM number of Kcal and C. (Bottom graph) number of grams of food consumed during post-test consumption of study foods. ANCOVA revealed that the participants in the Variety group consumed significantly more energy and grams of food than those in the Same group ($p = .037$ and $.007$, respectively).

Figure 2.

Dietary variety decreases the rate of habituation for motivated responding for food. A. (Top graph) Mean ± SEM number of responses made in each trial for access to food. ANCOVA revealed that subjects working for access to the Same food repeatedly (closed circles) habituated at a faster rate than those working for access to a Variety of foods (open circles), regardless of the energy density (ED) of the foods ($p < .05$). B. (Middle graph) Mean ± SEM Kcals consumed during the testing session. There was a main effect of variety ($p = .002$) and ED ($p < .0001$) and significant interaction between food variety and ED. Post-hoc analyses revealed that variety increased energy consumption in the high energy density (HED), but not the low energy density (LED) group ($p = .003$). C. (Bottom Graph) Mean ± SEM number of

grams of food consumed during the test. ANCOVA analysis showed that subjects in the Variety groups consumed significantly more grams than those in the Same groups, but there was no effect of the ED of food ($p < .05$).

Table 1

Characteristics of Participants in the Experiment for Variety Food and the Same Food Conditions for Experiment 1

Descriptive variables	Group			
	Variety		Same	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
<i>N</i>	9		9	
Men	4		4	
Women	5		5	
Age (years)	11.22	1.21	10.95	0.97
Socioeconomic status	51.33	11.26	49.88	12.67
BMI percentile	69.79	22.23	65.10	24.80
Restraint scores	2.67	2.55	5.13	4.09
Subjective hunger	1.67	0.50	2.38	1.06
Self-reported calories (Kcal)	926.09	261.00	845.03	294.19
Olfactory function (mm)	264.44	15.09	262.50	16.69
Baseline salivation (g)	0.76	0.53	1.02	0.66

Note. BMI = body mass index.

Table 2
Low and High Energy Density Foods Used for Experiment 2

Food	Kcal (40 g portion)	Energy density (Kcal/g)
Low energy density foods		
Yogurt	21.18	0.53
Pudding	36.36	0.91
Baby carrots	15.20	0.38
Grapes	28.40	0.71
Mandarin oranges (light syrup)	24.76	0.62
Pineapple (natural fruit juice)	21.24	0.53
Peaches (extra-light syrup)	17.70	0.44
High energy density foods		
Hamburger (loaded)	95.48	2.39
Cheese pizza	94.20	2.36
Chicken nuggets	117.32	2.93
French fries	123.96	3.10

Characteristics of Participants in the Variety Food and the Same Food Conditions for Experiment 2

Table 3

Descriptive variables	Group									
	Low energy density					High energy density				
	Variety		Same			Variety		Same		
	M	SD	M	SD	N	M	SD	M	SD	N
N	8		9		9	9		9		9
Men	4		5		4	4		5		5
Women	4		4		5	5		4		4
Age (years)	11.16		10.67			11.05		10.44		
BMI percentile *	52.08	1.21	71.14	1.18		75.75	0.93	55.83	0.93	1.27
Restraint scores	3.25	26.90	4.44	19.90		4.11	16.90	3.67	16.90	12.17
Socioeconomic status	46.75	2.05	38.11	3.13		52.83	2.37	48.11	2.37	2.74
Subjective hunger	2.88	10.10	3.00	10.74		4.33	16.90	3.89	16.90	7.41
Self-reported energy (Kcal) *	872.61	0.84	509.56	1.23		636.06	0.87	462.77	0.87	1.36
		296.80		160.54			414.47		414.47	264.97

Note. BMI = body mass index.

* Significantly different among the groups ($p < .05$).