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Research report

Food characteristics, long-term habituation and energy intake. Laboratory and field studies ☆

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ABSTRACT

Greater food variety is related to increased energy intake, and one approach to reduce food intake is to reduce food variety. The effects of varying the variety of foods at the dinner meal to reduce energy intake was assessed in laboratory and field experiments. Experiment 1 randomly assigned 31 overweight children to one of three conditions that provided one laboratory meal per day over a week. Conditions were the SAME macaroni and cheese, SIMILAR types of macaroni and cheese, or a VARIETY of high-energy-dense foods. On days 1 and 5 all children consumed the same macaroni and cheese meal. Results showed significant differences in energy consumed between SAME and SIMILAR versus VARIETY from day 1 to 5, with SAME and SIMILAR decreasing and VARIETY increasing energy intake. Trials to habituation, a potential mechanism for the variety effect, showed the same pattern of between group differences as energy intake. Experiment 2 randomly assigned 30 overweight children to conditions that provided the SAME, SIMILAR or VARIETY of high-energy-dense entrees along with a variety of low-energy-dense dinner entrees to eat in their homes for 4 weeks. Results showed significant between group differences in energy intake across weeks, with significant decreases over weeks for the SAME and SIMILAR versus VARIETY groups. The pattern of results across the experiments shows the same pattern of reduction in energy intake if children eat the same or similar characteristics of foods (types of macaroni and cheese), which may provide ideas about how to develop dietary variety prescriptions that can reduce intake and be tested in clinical trials.

Introduction

Food variety is reliably related to higher energy intake as evidenced by a consistent body of research in the laboratory and natural environment (McCrory et al., 1999; Raynor & Epstein, 2001). Research has also shown that success in behavioral treatment programs is predicted by the level of dietary variety. For example, weight loss is associated with consuming a reduced variety of foods in the general categories of high-fat foods or fats, oils and sweets (Raynor, Jeffery, Tate, & Wing, 2004). Similarly, persons successful with long-term maintenance of weight loss consumed less variety than recent weight loss participants in all food groups except fruit and combination foods (Raynor, Jeffery, Phelan, Hill, & Wing, 2005). Based on these data, one approach to treating obesity and reducing energy intake is to reduce the variety of high-energy-dense foods in the meal plan (Raynor & Epstein, 2001; Raynor, Niemeier, & Wing, 2006; Raynor & Wing, 2006; Raynor et al., 2005). Preliminary tests in obese persons showed that reducing the variety of snack foods for one-week reduces hedonic ratings of targeted snack foods (Raynor & Wing, 2006). Similarly, reducing the variety of snack foods for weight loss participants reduced hedonic ratings of these foods compared to usual variety conditions (Raynor et al., 2006).

One of the gaps in knowledge about how to reduce the variety of foods to reduce energy intake is a lack of understanding regarding what degree of difference in the properties of a food constitutes variety. Is it necessary to consume exactly the same food repeatedly, or will people reduce food and energy intake if they regularly consume variations of the same type of food? Research on habituation may provide ideas relevant to understanding how similarities or differences in food characteristics may result in changes in food intake. Habituation refers to a reduction in behavioral or physiological responses to repeated stimuli. Research indicates that the

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phenomenon reliably occurs with foods (Epstein, Temple, Roemmich, & Bouton, 2009). One common habituation paradigm is the variety paradigm, which tests whether habituation is slower when presented a variety of foods rather than one food presented repeatedly (Epstein, Temple, Roemmich, & Bouton, 2009b). Habituation can also be studied using a stimulus specificity paradigm, in which a response is observed to decrease after repeated food stimulation, and that the response rate can be recovered, or increase, after a different food is presented (Epstein et al., 2009b). The rate of habituation to a food is correlated with energy intake and body weight, with slower habituation to a food predicting greater energy intake (Epstein et al., 2009a; Temple, Giacomelli, Roemmich, & Epstein, 2008). Slower habituation is also cross-sectionally associated with overweight and obesity (Epstein, Paluch, & Coleman, 1996; Temple, Giacomelli, Roemmich, & Epstein, 2007), and slow habituation to repeated food cues is prospectively correlated with weight gain in non-overweight children (Epstein, Robinson, Roemmich, & Marusewski, 2011).

In previous work, we used the stimulus specificity paradigm to assess the relationship between characteristics of foods and habituation within one eating bout. All subjects first habituated to repeated servings of macaroni and cheese, and then were randomly assigned to groups that were provided with more macaroni and cheese, different but similar types of macaroni and cheese, or a different food (chicken nuggets) within a single test session. Results showed stimulus specificity and recovery of responding for food for participants provided either the different types of macaroni and cheese or the different food, suggesting habituation within a meal is specific to the exact food being presented (Epstein, Robinson, Roemmich, Marusewski, & Roba, 2010). Habituation to food has traditionally been studied within one meal or eating bout (Epstein et al., 2009b), as above, but recent research has shown that repeatedly presenting the same meal daily for a week results in reduced energy intake as well as more rapid habituation versus once per week for 5 weeks (Epstein, Carr, Cavanaugh, Paluch, & Bouton, 2011), which is one potential mechanism for the variety effect on food intake (Epstein et al., 2009b). The translation of this research to a clinical intervention will require an understanding of stimulus specificity of habituation over multiple days and meals, rather than just within a meal. The effect of food specificity on longer-term habituation and energy intake may be different from short term habituation. In a one session study participants may show different responses to stimuli that differ, such as different types of macaroni and cheese. However, if the foods that are different share some common characteristics, repeated food presentations over meals may enhance generalization of responding across these foods, such that participants could respond similarly to different types of macaroni and cheese (Epstein et al., 2009b).

Two experiments were conducted to begin to translate research on variety to intake over days and multiple meals. Experiment 1 was a five-day laboratory experiment designed to assess energy intake and responding for food over days for children who were provided the same macaroni and cheese meal, similar types of macaroni and cheese, or a variety of non-macaroni and cheese meals. Experiment 2 was a four-week field study designed to test eating at home for children provided dinner entrees over a month. In Experiment 2 children could choose between low-energy-dense (LED) or high-energy-dense (HED) entrées to eat for dinner. Between conditions, the choices for the HED entrées were either the SAME macaroni and cheese entree, a choice among SIMILAR types of macaroni and cheese entrees, or a VARIETY of non-macaroni and cheese entrees. This paradigm provided the opportunity to study changes in energy intake in the home as a result of reduced variety. In addition, the paradigm assessed whether reducing variety of HED foods reduces consumption of HED entrees while increasing choice and consumption of LED entrées, leading to a reduction in energy intake for that meal.

Experiment 1: Food characteristics and energy intake over 1 week

Method

Participants

Participants were 14 female and 17 male 8–12 year old overweight children recruited through an existing database, and advertisements via flyers and direct mailings. Participants were recruited from June to September, 2010. Children were considered overweight if they were at or above the 85th Body Mass Index (BMI) percentile for age and sex (Kuczmarski et al., 2002). Exclusionary criteria included: taking medications that might affect appetite (e.g. methylphenidate), medical or psychological conditions that might affect eating (e.g. eating disorders, upper respiratory illness, diabetes), current developmental disability or psychological disorder or unwillingness to eat the foods in the study. 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.

Procedure

Parents of participants were screened by telephone and eligible participants were scheduled for five consecutive daily visits to the laboratory between the hours of 4:00–7:30 PM Monday through Friday during a time the children normally consumed dinner. One child needed to cancel a visit after he/she was enrolled in the study and this child completed the study Tuesday through Saturday. Children were stratified by gender and randomly assigned to one of three groups: SAME, SIMILAR or VARIETY. Children ate their normal breakfast and lunch, but did not eat or drink anything except water in the 3 h prior to the appointment. Children also did not consume the study foods 24 h prior to the appointment. Participants in all groups were asked to abstain from eating macaroni and cheese outside of the laboratory during the duration of the experiment and participants in the VARIETY group were asked to refrain from eating their assigned foods 24 h prior the appointment.

Upon arrival at the laboratory, parents and children completed consent and assent forms, parents filled out a demographic questionnaire, and children's height and weight were obtained. To ensure compliance with the experimental protocol, children completed a same day food recall and recalled all of the foods consumed upon leaving the laboratory the previous day. Children then completed food liking and hunger questionnaires. On days 1 and 5, participants in each group completed an habituation task, in which they played a computer game to repeatedly earn 100 kcal portions of Kraft Macaroni and Cheese®. During days 2–4, participants freely consumed different foods based on their group. Children in the SAME group consumed Kraft Macaroni and Cheese® on each day, those in the SIMILAR group consumed different types of macaroni and cheese (Kraft® Spiral, Spongebob Squarepants, Cheddar Explosion, Whole Grain and White Cheddar Macaroni and Cheese), and those in the VARIETY group consumed a variety of HED foods. The study was conducted over five days based on previous research on long-term habituation (Epstein et al., 2011). Studying the children over 5 days provided the opportunity to compare consumption of the same food (Kraft Macaroni and Cheese) in the habituation task after differential treatment on days 2–4.

After the experimental task on day 5, participants again completed hunger and food liking questionnaires. At the end of the

final test session, participants completed the Dutch Eating Behavior Questionnaire adapted for children (Hill & Pallin, 1998), which assesses dietary awareness. Finally, parents and children were debriefed about the purpose of the study and were given written materials about the theoretical rationale behind the experiment. Participants were compensated with $20 Target gift certificates for each completed test session with a bonus of a $20 gift certificate for completing all 5 test sessions, for a total of $120 in gift certificates.

Laboratory environment

The laboratory was specially constructed for eating experiments and was equipped with an air delivery system that circulates new air through each room approximately 10 times per hour. Experimental rooms had intercom systems and a closed circuit video system so the experimenter could observe and communicate with the participant.

Measurement

Demographics

Family income and racial/ethnic background of parents and child were obtained using a standardized questionnaire.

Anthropometrics

Youth weight was assessed with a digital scale (Tanita™ BWB-800P Arlington Heights, IL). Height was assessed using a Digi-Kit™ digital stadiometer (North Bend, WA). On the basis of height and weight data, BMI was calculated as kg/m^2. Children were considered overweight or at risk for overweight if they were at or above the 85th BMI percentile (Kuczmarski et al., 2002).

Food hedonics and hunger

The participants' liking of study foods was assessed at the beginning and end of experimental sessions 1 and 5. Liking was determined using a 5-point Likert type scale anchored by "Do not Like" and "Like very Much." Participants in the SIMILAR and VARIETY groups also ranked the study foods in each of the two respective conditions from one (most liked) to six (least liked). These two groups received their top three favorite foods other than the original macaroni and cheese during the three *ad lib* sessions (sessions 2–4) of the study. Hunger was assessed at the beginning and end of each experimental session using a 5 point Likert-type scale anchored by "Extremely Hungry" and "Extremely Full."

Same Day and previous day food recall

To ensure compliance with the protocol (not eating or drinking anything other than water for 3 h prior to testing and not eating study foods within the last 24 h), the child (with the assistance of the parent) was asked to recall his/her dietary intake for days 1–5 as well as to recall any food consumed after leaving the laboratory the previous day.

Habituation task

Habituation of motivated responding for a food was assessed using a computer task in which children could earn points for the food by moving the cursor over a flashing red square on a computer screen and clicking the mouse button. Points could be earned on a variable interval 120 ± 42 s, and an adjacent square flashed green when a point was earned. Earning a point provided the children with access to 100 kcal portions of Kraft® Macaroni and Cheese. On a variable interval 120 s schedule, participants were rewarded with one point for the first response made after approximately 120 s had passed, and they received the food immediately after each point was earned and could continue to work on the habituation task while eating. The variable interval schedule was based on basic animal research on habituation of motivated responding for food (McSweeney, Hinson, & Cannon, 1996; McSweeney & Swindell, 1999). The intervals were determined by a computer algorithm generated within the constraints that they not be greater than or less than 35% of 120 s. The task was implemented over 24 min, divided into 12, 2-min trials, which is sufficient time to observe habituation in previous experiments (Epstein et al., 2009b; Temple et al., 2007). If they no longer wanted to earn access to food they could go to another table and engage in the alternative activities, including age appropriate crosswords, word searches and mazes, which were freely available. Participants could move freely between the computer and activity stations. Water was provided ad libitum throughout the duration of the experiment. Trials to habituation was defined as the last 2-min time block (from 1 to 12) in which responding for food was recorded. Foods were weighed before and after the session using an electronic scale (Denver Instrument XP-3000, Denver Instrument Company, Avada, Colorado) that was sensitive to 0.1 g; manufacturer's product information was used to compute the total energy intake of all foods consumed.

Ad Libitum eating sessions

On days 2–4, participants were provided with a tray containing 1200 kcal of food. Participants in the SAME condition received 1200 kcal of Kraft® macaroni and cheese (percent calories from fat, carbohydrates and protein = 42.2% fat, 48.8% carbohydrate, 9.0% protein) every day. Participants in the SIMILAR condition were provided 1200 kcal of one of their top three rated varieties of macaroni and cheese, presented in a randomized order across days. Variations in the macaroni and cheese included variations to the taste, appearance or texture of the macaroni and cheese. The SIMILAR types of macaroni and cheese had similar percent energy from fat (36–43.6%), carbohydrates (46.6–53.3%) and protein (8.3–10.7%) in comparison the SAME macaroni and cheese. Participants in the VARIETY condition were provided with 1200 kcal of one of their top three rated HED entrees, presented in a randomized order across days, and a selection of condiments. The variety foods included Tyson® Southwest Flavor Chicken Nuggets (69.2% energy from fat, 16.1% energy from carbohydrate and 14.6% energy from protein), Wegmans® Four Cheese Pizza (27.3% energy from fat, 55.2% energy from carbohydrate, 17.6% energy from protein), Wegmans® Mozzarella Sticks (43.8% energy from fat, 34.6% energy from carbohydrate, 21.6% energy from protein), White Castle® cheeseburgers (48.9% energy from fat, 33.2% energy from carbohydrate, 17.9% energy from protein), and Gorton's® Crunchy Fish Sticks (55.5% energy from fat, 28.3% energy from carbohydrate, 16.0% energy from protein). Condiments were available for all variety entrees and included 30 calorie portions of honey mustard, pizza sauce, barbeque sauce and tomato ketchup. Participants could eat as much or as little of the presented foods as they liked. Water was provided ad libitum.

Participants remained in the experimental room for at least 24 min, after which they could stay for as long as they liked to finish the meal. Participants could move over to the activity table and engage in age appropriate crosswords, word searches and mazes when they no longer wanted to consume the food that was brought in for them. Foods were weighed before and after the session using an electronic scale (Denver Instrument XP-3000, Denver Instrument Company, Avada, Colorado) that was sensitive to 0.1 g; manufacturer's product information was used to compute the total energy intake of all foods consumed. The amount of food presented and the length of the *ad lib* session were equivalent to the length and amount of food that could be earned during the habituation task on days 1 and 5.

Analytic plan

Differences in participant characteristics by group (SAME, SIMILAR, or VARIETY) were analyzed using one way analysis of variance for continuous variables and Chi square analysis for categorical variables. Changes in trials to habituation, energy intake and liking and hunger were analyzed using repeated measures analysis of covariance with group (SAME, SIMILAR, or VARIETY) as the between subjects variable and day (1, 5) as the within subject variables, and baseline hunger on day 1 as a covariate. Baseline hunger on day 1 was included as a covariate because it was related to the change in energy intake ($r = 0.53$, $p = 0.002$) and changes in trials to habituation ($r = 0.59$, $p = 0.0005$). Hypothesis testing was used to test between group differences over time. Three participants, one from each group, did not follow the experimental protocol and were removed from all analyses. Analyses were performed using SYSTAT (Systat Software Inc. Chicago, IL).

Results

Characteristics of children by group are presented in Table 1. The average participant was 10.4 ± 1.3 (Mean ± SD) years of age, with zBMI of 1.79 ± 0.46. The majority of families had an income > US$50,000/year (64.5%) and 14 (45.2%) were minority, with 10 (32.3%) African American and 4 (12.9%) more than one race. There were no differences ($p > 0.05$) in baseline or demographic characteristics between children in the groups.

Energy intake of the groups on days 1 and 5 is shown in Fig. 1A. The ANCOVA indicated a significant group∗session interaction ($F(2, 24) = 4.69$, $p = 0.019$). Contrasts showed that children in the SAME ($F(1, 24) = 7.71$, $p = 0.01$) and SIMILAR ($F(1,24) = 5.97$, $p = 0.02$) groups reduced their intake from session 1 to 5 in comparison to the VARIETY group, which increased intake from sessions 1 to 5. There were no differences in energy intake over time between the SAME and SIMILAR groups ($F(1, 24) = 0.01$, $p = 0.92$). Similarly, the ANCOVA for change in trials to habituation showed a significant group∗session interaction ($F(2, 24) = 4.43$, $p = 0.023$). As shown in Fig. 2, contrasts showed that children in the SAME ($F(1, 24) = 7.83$, $p = 0.01$) and SIMILAR ($F(1, 24) = 4.92$, $p = 0.04$) groups showed a reduction in trials to habituation in comparison to the VARIETY group. There were no differences in trials to habituation from session 1 to session 5 between the SAME and SIMILAR groups ($F(1, 24) = 0.12$, $p = 0.73$).

Significant between group differences in energy intake were also observed for days 2–4 (Fig. 1B), when the differences in foods across groups were manipulated. The ANOVA for energy intake over days showed a significant group effect ($F(2, 24) = 5.49$, $p = 0.011$). Contrasts indicated that children in the SAME ($F(3, 22) = 3.54$, $p = 0.031$) and SIMILAR ($F(3, 22) = 4.12$, $p = 0.018$) groups consumed less energy on each day than children in the VARIETY group, with no differences in energy intake over time between the SAME and SIMILAR groups ($F(3, 22) = 0.11$, $p = 0.95$). The same pattern of energy intake on days 2–4 was observed if calories from condiments were not included ($F(2, 24) = 4.65$, $p = 0.02$), as children in the SAME group consumed 646.7 ± 83.9, 684.5 ± 91.3 and 604.9 ± 76.4, on days 2–4, children in the SIMILAR group consumed 603.4 ± 95.8, 623.2 ± 104.3, 539.4 ± 87.2 on days 2–4, and children in the VARIETY group consumed 866.2 ± 84.6, 918.0 ± 92.1, 945.8 ± 77.0 on days 2–4.

Analysis of entrée macronutrients showed significant differences in energy intake by group for days 2–4 for calories from fat (Fig. 3A; $F(2, 24) = 6.07$, $p = 0.007$), and protein (Fig. 3B; $F(2, 24) = 26.41$, $p < 0.001$), with the VARIETY group showing greater intake of these macronutrients than the SAME or SIMILAR groups ($p < 0.05$). No between group differences were observed for carbohydrates (Fig. 3C; $F(2, 24) = 0.23$, $p > .05$). In addition, no between group differences in changes over time were observed for pre-session hunger ($p = 0.90$), though a trend was observed for changes in pre-session liking ($p = 0.07$).

Table 1
Characteristics of children in Experiment 1.

Characteristic	SAME	SIMILAR	VARIETY	*p*
N	11	9	11	
Gender				
Males	5 (45.5%)	4 (44.4%)	5 (45.5%)	0.99
Females	6 (54.5%)	5 (55.5%)	6 (54.5%)	
Race				
Caucasian	6 (54.5%)	6 (66.7%)	5 (45.5%)	0.78
African American	3 (27.3%)	2 (22.2%)	5 (45.4%)	
More than one race	2 (18.2%)	1 (11.1%)	1 (9.1%)	
Parent's Income				
Under $29,999	2 (18%)	0 (0%)	4 (36%)	0.14
$30,000–$49,999	1 (9%)	1 (11%)	3 (27%)	
⩾$50,000	8 (73%)	8 (89%)	4 (36%)	
Age	10.1 ± 1.6	10.4 ± 1.0	10.8 ± 1.3	0.47
zBMI	1.8 ± 0.4	1.8 ± 0.5	1.8 ± 0.5	0.93
Percent overweight	41.8 ± 17.5	51.5 ± 31.3	46.9 ± 27.2	0.7
Hunger per day 1	2.5 ± 0.8	2.7 ± 0.7	2.2 ± 0.8	0.38
Liking macaroni and cheese day 1	4.3 ± 0.5	3.9 ± 0.8	3.7 ± 0.6	0.14
Trials to habituation session 1	7.7 ± 3.6	6.1 ± 2.8	6.7 ± 3.7	0.58

Discussion

These results showed that consuming the same or similar foods over days versus a variety of foods was associated with a differential change in energy intake and habituation. Children receiving the same or similar foods showed a reduction in energy intake and trials to habituation from day 1 to 5, while children who received a variety of HED foods showed an increase in energy intake and trials to habituation. One explanation for this pattern of data is that repeated presentation of members of a type of food with similar food characteristics, such as macaroni and cheese, leads to habituation to foods with these characteristics, which leads to reduced energy intake over days. The results of repeated exposure to a food over days in this study and in previous research (Epstein et al., 2011) has been in the context of eating in a laboratory setting, and it is important to assess if manipulating access to characteristics of the same, similar or different types of foods influences dinner intake in the natural environment in the same way. This was the goal of Experiment 2.

Experiment 2: Food characteristics and energy intake over a month

Method

Participants

Participants were 30 overweight (15 females and 15 male) 8–12 year old children recruited in the same way as Experiment 1 from flyers, direct mailings and from an existing database. Participants were recruited from January to September, 2011. Exclusion criteria were similar to Experiment 1 with the addition of at least a moderate liking of Kraft Original Macaroni and Cheese® (⩾3 on a 5 point Likert type scale) and at least a moderate liking and willingness to consume four other varieties of macaroni and cheese and four other HED dinner entrees. Other exclusion criteria included at least one parent agreed to help their child prepare their selected meal and record dietary intake; regular consumption of Kraft Original Macaroni and Cheese® as reported of at least once a month; children had to reside primarily in one household, and children had to report eating on average five or more dinners at home each week.

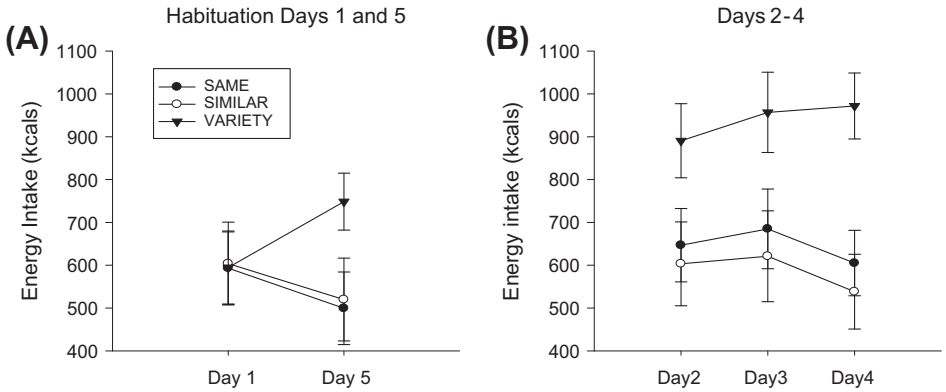

Fig. 1. Energy intake for children randomized to SAME, SIMILAR and VARIETY conditions for macaroni and cheese on days 1 and 5 (A) and for experimental foods on days 2–4 (B) (mean ± SEM).

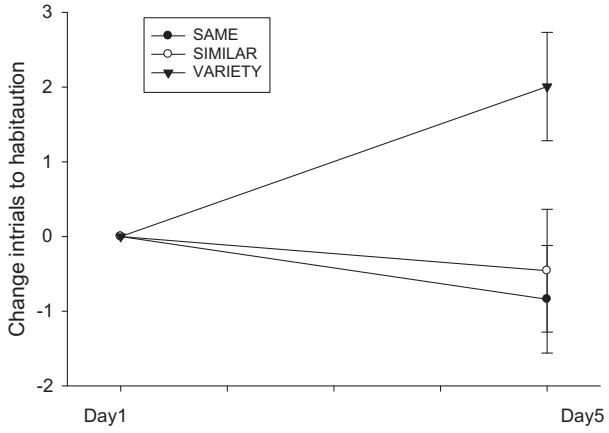

Fig. 2. Change in trials to habituation for children randomized to SAME, SIMILAR and VARIETY conditions for macaroni and cheese on days 1 and 5 (mean ± SEM).

Procedure

Parents of potential participants were screened by phone, and eligible families attended an orientation session at which height and weight measurements of the child were taken and children that met the criteria were scheduled for a screening session a week later. During the next week, parents and children were asked to record their dinner and evening snacks in a habit book to simulate procedures that would be followed for the month long study. At the screening assessment, habit books were reviewed together with the parent and child to ensure thorough and accurate recording. Parents completed demographic information and children completed questionnaires about food preference. Following completion of the screening appointment, eligible families were scheduled for five weekly visits during their normal dinner time between the hours of 4:00PM and 7:00PM.

Children were stratified by gender and randomly assigned to one of three groups: SAME, SIMILAR and VARIETY. During the first week of the study children were asked to eat at least one full serving each day at dinner of an assigned HED entrée along with healthy sides and beverages. Children assigned to the SAME condition consumed the same type of macaroni and cheese for dinner each night, while children assigned to the SIMILAR condition consumed different types of macaroni and cheese each night. Children assigned to the VARIETY group received seven different HED entrees during the week. During weeks 2–4 children were given a choice of a HED or LED entrée along with healthy sides and beverages. All HED and LED dinner entrees were provided to families at no charge throughout the study and were chosen by the families the week prior (see below). Serving sizes of the entrees were based upon manufacturer's labels. Many of the foods provided one serving per package, but if the package included multiple servings, families were provided measurement tools (measuring cups, rulers, examples of serving sizes) which they could use to measure one serving. Children were also asked to fill out a menu for foods they would like to consume the next week. The SAME group had no choice for the HED entrée, but could choose which one to seven LED entrees they would receive each week. Families in the SIMILAR group could choose five–seven versions of macaroni and cheese, while families in the VARIETY group could choose five–seven HED entrees, and one to seven LED entrees they would receive each week. All groups chose HED and LED entrees for seven days so that on each day, the child had a choice between an HED or LED entrée. The VARIETY group had the same opportunities to consume low- or high- energy- dense dinners, the difference was in the SAME group the only high energy dense entrée was usual macaroni and cheese, while in the SIMILAR group, the only high energy dense entrees were variations of macaroni and cheese. Criteria for LED and HED entrees were based on Volumetrics (Rolls, 2005), a dietary approach that categorizes foods based on their energy density. Foods were considered low in energy density if they were less than or equal to 1.5 kcal/gram, and medium to high in energy density if they were greater than 1.5 kcal/gram. Characteristics of the LED and HED entrees available for children are presented in Table 2.

To ensure that participants were not exposed to the same stimulus repeatedly, participants in the SIMILAR and VARIETY groups were told that they should not have the same HED dinner entrée two nights in a row and no more than twice in one week. No restrictions were made on the variety and number of consecutive days that children could have LED dinner entrées for any condition. Dinner and evening intake including dessert was recorded daily in a habit book.

During each weekly visit, families met with a staff member to discuss program goals, recording and receive study food. Separate study handbooks were provided to parents and children to ensure families adhered to the study protocol. Parents were encouraged to praise and reinforce their children for adhering to the study protocol and monitoring their intake. The study handbook provided parents in all conditions with an introduction to the study in which we told them that the purpose of the study was to vary the amount of variety in their child's dinners. They were told they would be provided entrees for each child's dinner to consume during the next week at each weekly meeting, and that the entrees would include foods that differed in the fat and energy density. Parents were told what would occur in each visit, the monetary compensation

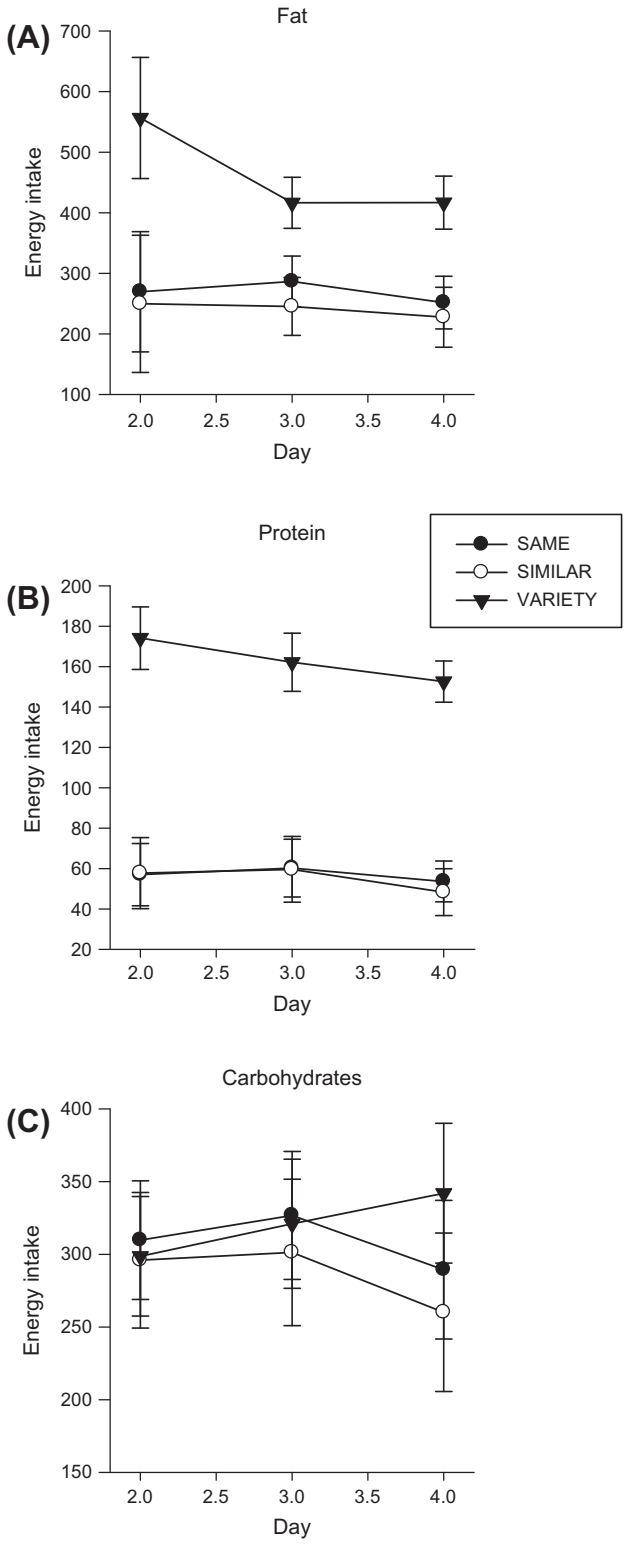

Fig. 3. Daily fat (A), protein (B) and carbohydrate (C) intake for children randomized to SAME, SIMILAR and VARIETY conditions (mean ± SEM).

received at each visit for completing study tasks, details about food recording, the point system for recording, consuming study foods, completing tasks and earning money, lists of approved side dishes and beverages (mainly fruits and vegetables, milk and water as beverages as well as grains such as pasta and rice). Families were provided a guide for eating out so they could follow the experimental protocol if they ate food at restaurants. Tips were provided to get the whole family involved in meal preparation and help the child adhere to the protocol; and ways to problem solve issues that might come up in relation to adherence to the protocol.

A serving size chart of foods available in their condition was included, as well as generic healthy eating tips which included information about how to define energy density, and cooking tips about how to cook healthier, including 14 healthy recipes all under 5 g fat per serving which could be used as approved substitutes to the study provided foods. All groups received the same types of healthy dinners, and families in any group could consume a high-energy-dense or a low-energy-dense dinner that was provided to them. Families were all told that increasing the variety of low energy dense foods could lead to increase in eating low energy dense foods. The only information that was different between groups was that parents of children in the SAME and SIMILAR groups were told that reducing variety of high energy dense, less healthy foods may lead to reduced consumption of these foods, consistent with the between group differences. Child handbooks were written for 8–12 year-old children and included information on food recording, the point system, payment, food lists, eating tips and guidelines and a recipe list.

Positive reinforcement in the form of praise and monetary incentives were used to facilitate adherence to the study protocol. Children earned up to $180 in the form of Target gift cards and cash for participation. Children earned a $20 gift certificate to Target for each completed laboratory visit with an additional $20 gift certificate for completing all five sessions. Additionally, children could earn up to $15/week for recording in their habit book and meeting the study goals, with $7 for recording each day and $7 for having either a HED or LED entrée along with healthy sides and beverages for their dinner, with a bonus $1 for recording and meeting study goals every day.

Measurement

Several variables were measured similar to data collected in Experiment 1. These included demographic variables, weight and medical history, and anthropometric variables.

Measurement of dinner and evening eating

Parents and children worked together to record the child's dinner and evening intake in a daily habit book. All families were provided training and instructions to record, and were provided measurement utensils, rulers and examples of portions sizes. During screening all families recorded intake for one week using similar methods to the study, which provided the opportunity to decline participation to families who would not record or who were incomplete recorders, and feedback on recording could be provided to families during this period. Specific instructions about recording were provided to all families in their study handbook, and all habit books were reviewed for completeness and accuracy for evening recording. Parents and children were trained to work together to record accurate amounts of food in their habit book. The recording was made easier by the fact that all entrees were provided to families, and the entrees were all packaged foods that included usual serving size information. Many of the packages were single servings, but when multiple servings were provided, families were told to portion out the food prior to serving. To enhance accuracy of recording, families were encouraged to use the training and measurement tools provided to estimate the amount consumed. Food records were reviewed weekly and families were asked to identify dinner, dessert and evening snacks in the diet records. Since the experimental manipulation only involved the dinner meal, evening snacks including desserts were analyzed separately. Data from the habit books were used to assess whether children met their dinner goals of having either one of the provided

Table 2
Characteristics of foods available for evening entrees.

Food presented	kcal	ED	Fat (g)	CHO (g)	Pro (g)
High-energy-dense entrees					
SAME and SIMILAR conditions					
Kraft macaroni and cheese dinner, original flavor	400	2.04	19	49	10
Kraft macaroni and cheese dinner, spirals	420	2.14	20	48	10
Kraft macaroni and cheese dinner, nickelodeon spongebob	420	1.93	20	49	9
Kraft macaroni and cheese dinner, white cheddar	380	1.99	15	50	10
Kraft macaroni and cheese dinner, 50% whole grain	390	1.99	17	50	8
Kraft macaroni and cheese dinner, thick 'n creamy	410	1.81	18	52	10
Kraft macaroni and cheese dinner, cheesy alfredo	400	1.94	17	51	9
Velveeta shells and cheese, original	360	1.60	12	49	13
Kraft macaroni and cheese dinner, three cheese	400	1.90	17	51	9
VARIETY condition					
Kraft macaroni and cheese dinner, original flavor	400	2.04	19	49	10
Gorton's fish sticks, crunchy golden	230	2.52	14	16	9
Tyson chicken nuggets (Southern Style)	270	3.21	21	11	10
Wegmans mozzarella sticks	190	2.50	9	16	10
White castle cheeseburgers	310	2.98	17	26	14
Wegmans French bread pizza, cheese	310	2.11	9	42	15
Smucker's uncrustables PB & J sandwich	210	3.62	9	25	6
Banquet pot pie, chicken	370	1.87	21	35	10
Hot pockets stuffed sandwiches, ham 'n cheese	290	2.27	12	35	10
Tyson Any'tizers chicken wings, boneless, honey BBQ	210	2.62	12	13	11
State fair corn dogs, honey batter	200	2.63	11	22	6
Hot pockets side shots sloppy joes	270	2.12	7	42	10
Wegmans potato skins	160	2.42	11	11	5
Stouffer's corner bistro philly-style steak & cheese sub	370	2.18	16	39	20
Low-energy-dense entrees					
Campbell's chunky soup, classic chicken noodle	120	0.46	3	14	8
Lean Cuisine one dish favorites, Stir fry, chicken Teriyaki	250	0.98	2	46	12
Campbell's soup, condensed, vegetarian vegetable	90	0.36	0.5	18	3
Campbell's Spaghetti O's, original	170	0.67	1	35	6
Campbell's soup, condensed, tomato	90	0.39	0	20	2
Lean cuisine comfort classics glazed Turkey Tenderloins	250	0.98	5	38	13
Lean Cuisine cheese ravioli with chunky tomato sauce	220	0.93	5	33	11
Cedarline burrito, beans, rice and cheese style	260	1.52	1	48	13
Gardenburger, veggie original	110	1.55	3.5	15	6
Mrs. T's potato cheddar pierogies	170	1.49	2.5	33	5
Wegmans penne rigate (dry)*	210	1.61	1	42	7
Wegmans tomato basil pasta Sauce*	70	0.56	2.5	12	2
Tyson chicken breast strips	100	1.19	2	1	21
Gorton's grilled tilapia, signature	80	0.90	2.5	0	14

Note: kcal = calories, CHO = carbohydrates, pro = protein, ED – energy density.
* *Note*: Pasta was combined with sauce for an overall ED of 1.10.

HED and LED entrees and all healthy sides; as well as to compute average calories consumed per day during dinner, evening snacks and the total evening intake combining dinner and evening snacks across weeks. Calories and macronutrients consumed were calculated from Nutritionist Pro (Nutritionist Pro version 4.5, Axxya Systems, 2010) or food manufacturer information. Habit book data were also used to assess between group differences in choice of LED entrees.

Analytic plan

Differences in participant characteristics by group (SAME, SIMILAR, or VARIETY) were analyzed using one way analysis of variance for continuous variables. Chi-square analyses were used for categorical variables. Changes in energy intake for dinner, evening snacks, and total evening intake and intake of healthy LED entrees were analyzed using analysis of variance (ANOVA) with group (SAME, SIMILAR, or VARIETY) as the between subjects variable and week (1, 2, 3, 4) as the within subjects variable. Hypothesis testing was used to test for group differences in energy intake or choice of LED entrees. Data were analyzed with and without days deleted if participants were sick. There were very few sick days with no differences observed whether all days were studied or sick days deleted, and all results are presented with all days included. Analyses were performed using SYSTAT (Systat Software Inc. Chicago, IL).

Results

The average participant was 10.3 ± 1.3 (Mean ± SD) years of age with zBMI of 1.8 ± 0.5. The majority of families had an income > US $50,000/year (60%) and 7 (23.3%) were minority. Four (13.3%) were African American and 3 (10%) were more than one race. No differences in any of the participant characteristics (Table 3) were observed.

The ANOVA for total energy intake (dinner and snacks combined) revealed (Fig. 4A) a significant group∗week interaction ($F(6, 81) = 3.26$, $p = 0.006$). Contrasts indicated that children in the SAME ($F(1, 27) = 9.68$, $p = 0.004$) and SIMILAR ($F(1, 27) = 10.21$, $p = 0.004$) groups showed a reduction in dinner energy intake over time in comparison to the VARIETY group, while there were no differences between the SAME and SIMILAR groups ($F(1, 27) = 0.03$, $p = 0.88$). The ANOVA for dinner energy intake (Fig. 4B) also indicated a significant group∗week interaction ($F(6, 81) = 3.08$, $p = 0.009$). Contrasts showed that children in the SAME ($F(1, 27) = 4.63$, $p = 0.04$) and SIMILAR ($F(1, 27) = 8.86$, $p = 0.006$)

Table 3
Characteristics of children in Experiment 2.

Characteristic	SAME	SIMILAR	VARIETY	*p*
N	11	10	9	
Gender				
Males	6 (54.5%)	4 (40%)	5 (55.6%)	0.74
Females	5 (45.5%)	6 (60%)	4 (44.4%)	
Race				
Caucasian	8 (72.7%)	8 (80%)	7 (77.8%)	0.98
African American	2 (18.2%)	1 (10%)	1 (11.1%)	
More than one race	1 (9.1%)	1 (10%)	1 (11.1%)	
Parent's Income[a]				
Under $29,999	1 (10.1%)	0 (0%)	1 (11.1%)	0.69
$30,000–$49,999	3 (30.0%)	3 (33.3%)	1 (11.1%)	
$50,000 or greater	6 (60.0%)	6 (66.7%)	7 (77.8%)	
Age	10.2 ± 1.4	10.5 ± 1.5	10.3 ± 0.9	0.83
Child baseline zBMI	1.9 ± 0.4	1.9 ± 0.4	1.7 ± 0.6	0.59
Child percent overweight	44.9 ± 15.9	50.9 ± 24.2	43.9 ± 28.7	0.77
Baseline liking				
Mac *n* cheese	4.7 ± 0.5	4.3 ± 0.8	4.3 ± 0.9	0.34
Healthy entrees	3.4 ± 0.8	3.1 ± 0.8	2.9 ± 1.0	0.42
Calories consumed in evening week 1				
Dinner	686.1 ± 155.5	747.3 ± 226.9	539.0 ± 168.5	0.06
Evening snack	192.7 ± 99.2	186.7 ± 186.3	189.6 ± 157.0	1
Total	878.8 ± 201.5	934.0 ± 219.7	728.6 ± 269.7	0.15

[a] Income reported for 28 participants.

groups reduced dinner energy intake over time in comparison to the VARIETY group. There were no differences in energy intake over time between the SAME and SIMILAR groups ($F(1, 27) = 0.84$, $p = 0.37$). No differences in snack intake (Fig. 4C) over time were observed ($F(6, 81) = 0.57$, $p = 0.75$) and there were no main effects of group or time.

The ANOVA on total evening carbohydrate calories (Fig. 5A) showed a significant group∗week interaction ($F(6, 81) = 2.35$, $p = 0.038$) as well as a significant main effect of time ($F(3, 81) = 22.94$, $p < 0.001$). Contrasts showed that children in the SAME group ($F(1, 27) = 7.48$, $p = 0.01$) and SIMILAR group ($F(1, 27) = 9.28$, $p = 0.005$) consumed significantly fewer carbohydrate calories in comparison to the VARIETY group. There were no differences in carbohydrate calories between the SAME and SIMILAR groups ($F(1, 27) = 0.15$, $p > 0.05$). The ANOVA on total evening fat calories (Fig. 5B) showed a significant group∗week interaction ($F(6, 81) = 3.70$, $p = 0.003$) as well as a significant main effect of time ($F(3, 81) = 40.18$, $p < 0.001$). Contrasts showed that children in the SAME group ($F(1, 27) = 11.12$, $p = 0.002$) and SIMILAR group ($F(1, 27) = 9.91$, $p = 0.004$) consumed significantly fewer fat calories in comparison to the VARIETY group. There were no differences in fat calories between the SAME and SIMILAR groups ($F(1, 27) = 0.01$, $p > 0.05$). No significant differences were observed for group∗week ($F(6, 81) = 1.27$, $p > 0.05$), or by time ($F(3, 81) = 0.23$, $p > 0.05$) for protein calories (Fig. 5C).

To assess whether the children substituted healthier LED entrees for HED entrees when the variety of HED entrees was reduced, we examined the number of servings of LED entrees during weeks 2–4 (Fig. 6). Results of the ANOVA showed a significant group effect ($F(2, 27) = 5.81$, $p = 0.008$). Post-hoc contrasts combining the SAME and SIMILAR groups (which showed no differences in calories or macronutrients) versus the VARIETY group showed the SAME and SIMILAR consumed more LED entrees per week than the VARIETY group ($F(3, 25) = 4.09$, $p = 0.017$).

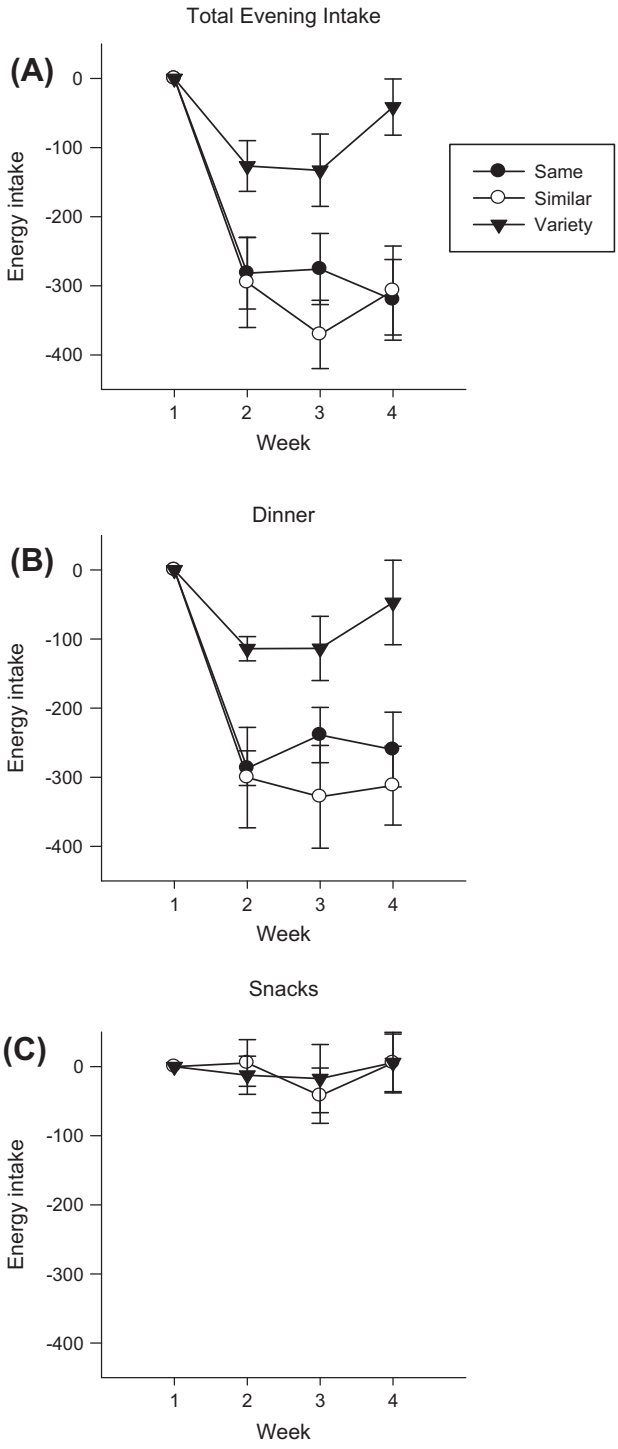

Fig. 4. Change in average weekly total evening energy intake (A), dinner intake (B) and snack intake (C) for children randomized to SAME, SIMILAR and VARIETY conditions. All participants consumed high-energy-dense entrees appropriate for their condition during the first week to ensure condition manipulation (mean ± SEM).

Discussion

Results of Experiment 2 showed that after repeated presentation of the same or similar foods for a week, continued access to that food as the only HED dinner entrée available to children led to reduced energy intake at dinner and in the evening in the natural environment, replicating the results of Experiment 1 in a new context. In Experiment 2, the decrease was for self-reported evening energy intake at home, rather than intake in the laboratory. The results suggest that presenting repeated access to either the same food or a number of foods with fundamentally similar characteristics may result in reduced energy intake of these foods. This is a

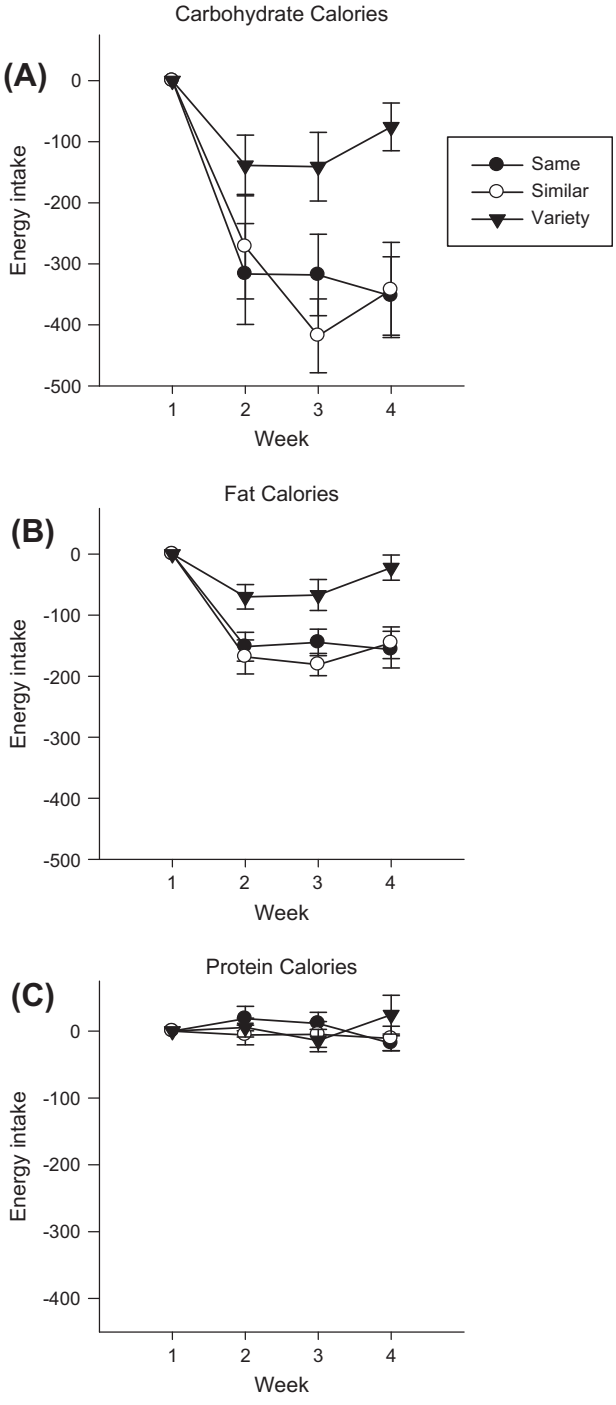

Fig. 5. Change in average weekly carbohydrate (A), fat (B) and protein intake (C) for children randomized to SAME, SIMILAR and VARIETY conditions. All participants consumed high-energy-dense entrees appropriate for their condition during the first week to ensure condition manipulation (mean ± SEM).

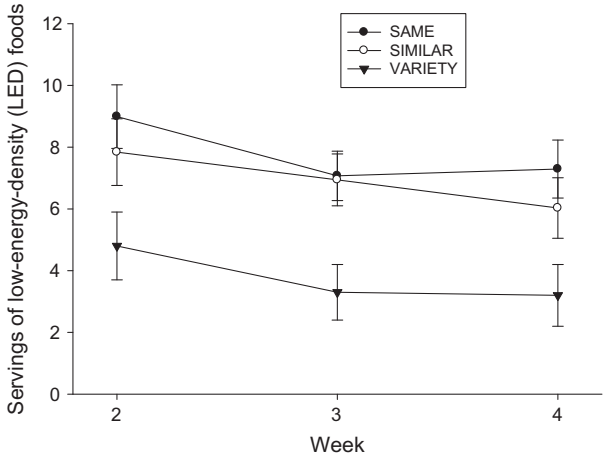

Fig. 6. Number of servings of low energy dense foods over weeks for children randomized to SAME, SIMILAR and VARIETY conditions (mean ± SEM).

new finding, as is the finding that the shift to healthier LED entrée foods is associated with significant reductions in evening fat and carbohydrate intake for the SAME or SIMILAR groups in comparison to the VARIETY group.

General discussion

The results of both experiments provide a consistent pattern of results showing that repeating access to the same or similar foods over days results in reduced energy intake in comparison to being provided a variety of foods. The laboratory experiment also showed that repeating the same or similar foods over days was associated with more rapid habituation, in addition to reduced energy intake, consistent with previous research on reduced access to daily repeated foods in a long-term habituation experiment (Epstein et al., 2011). While habituation was not measured in Experiment 2, it is reasonable to assume that consuming the same food over a week was also associated with habituation to that food, since that was observed in Experiment 1 and previous research (Epstein et al., 2011).

Extended exposure to a group of foods that share common characteristics, such as different types of macaroni and cheese, was associated with reduced energy intake in both experiments, with decreases similar to decreases observed for repeated access to the same food. The current research does not provide an indication of how many days of repeated presentation is needed to facilitate habituation to a group of foods with similar characteristics. It may be that repeated presentations of a class of foods with similar characteristics might be needed before generalization across commonalities of the foods is learned, and habituation to the similar characteristic of the food occurs. The number of learning trials may depend on the characteristics that foods differ on within a broader class of foods.

As habituation to a repeatedly presented food or stimulus class of foods is observed, participants may choose to substitute other foods that are available, and if those foods are lower in energy density, there is a good chance that reductions in energy intake will occur. Thus, repeating the same or similar foods over days may directly reduce energy intake for one class of foods, and as that occurs, people may choose other foods to eat. The other types of foods that are available may be very important in determining the effects of habituation. We have previously suggested that one approach to implementing the variety manipulation is to reduce variety of HED foods, while increasing the variety of LED foods (Epstein et al., 2011; Temple et al., 2008). Reducing variety of a particular HED food may have less effect on food choice if HED foods are available.

The results of these studies have potential application to the development of obesity treatment programs for youth. Reducing the variety of HED foods to reduce their intake while maintaining or increasing variety of healthier, LED foods is a simple approach to improving food choice, which in combination with other components of behavioral treatment approaches for children may have complementary or additive benefits. A major disadvantage of the present study is the absence of data on other meals besides dinner.

Our goal was to obtain the best quality data for evening intake when we were implementing the intervention, which involved having children and their parents keep detailed food records for evening food intake for a month. We were concerned that if we increased the recording burden to recording all foods consumed for a month, we would risk the quality of the evening intake data. Evening meals are one meal that parents and children usually eat together, and it may be easier for parents to assist with food recording for that meal than any other meal during the day. In addition, for many children, the dinner meal and evening intake represents a sizeable portion of their energy intake for the day (Roblin, 2007), so that even if that was the only meal that was targeted, and children did not compensate for reduced intake at other meals, these changes could result in important clinical benefits.

The biggest clinical benefits would come about from targeting reduced variety for multiple meals across the day. It is possible to implement the same strategy for breakfast, lunch and snacks, and clinical investigators have begun to explore reducing variety of snacks for adult weight control (Raynor & Wing, 2006; Raynor et al., 2006), and better weight loss has been observed for those with reduced variety of foods (Raynor et al., 2005). It is premature to attempt to apply the findings of these studies directly to clinical treatment, as the results may be different for other types of foods. While it is clear that different types of macaroni and cheese can be considered a functional stimulus class, or a set of stimuli that have equivalent effects on behavior, there are no data to consider what might constitute other types of functional stimulus classes. Different types of macaroni and cheese may be an ideal class of foods for studying the development of a functional stimulus class. For example, are different flavored potato chips a functional stimulus class of potato chips? Similarly, are different types of pizza a functional stimulus class of pizza? The answer to this may depend in part on characteristics of the foods, as well as how much learning or how many presentations are needed to establish a class of foods with similar characteristics as a functional stimulus class.

The overarching goal of these studies is to provide support for the idea that reducing variety of less healthy foods can lead to reductions in energy intake in laboratory and field contexts, which supports the next steps of translating this approach to clinical interventions. While the results of the two studies support this hypothesis, they have limitations that should be considered. First, the types of foods used in the variety condition included foods commonly consumed with condiments, such as ketchup, mustard, hot sauce, salsa, etc., while the macaroni and cheese dishes usually are not consumed with condiments. There are a variety of cheese sauces for the SIMILAR group, but that may not have the same effect on energy intake as adding condiments to foods. Adding condiments to foods could further increase the variety of entrees, because many entrees can be served with different condiments, which could reduce the rate of habituation to these entrees. It is possible that using foods in the same and similar groups that are typically served with condiments would be associated with less of a variety effect. The influence of condiments on the variety effect and habituation warrants further study. A second concern may be information in the handbook for the SAME and SIMILAR groups that informed families that reducing variety of less healthy foods can lead to reducing intake of these foods. Thus, it is possible that this information was important to obtain the greater reduction in energy intake for the SAME and SIMILAR food manipulation. While this information was not provided in Experiment 1, it is possible that the instructions interacted with the food intervention to maximize the benefit of the manipulation. Since this information would be provided in a clinical intervention, providing this information may increase the generalizability of the results if reducing the variety of HED foods is used as a component of a weight loss intervention, but it may obscure the independent effect of the food manipulation. A final concern is that the intake data was collected in Experiment 2 by self-report. It may have been useful to also collect uneaten food to more carefully measure food intake.

Attention to food variety provides a very different focus than usual behavioral components to treat obesity. It would be interesting to know if focusing on variety could have large enough effects on eating and energy intake to meaningfully alter body weight without many of the usual behavioral components which are challenging for people to maintain. Manipulating variety of foods within the home is by nature an environmental manipulation, and may have the advantages of environment manipulations over therapies that focus on self-control (Lowe, 2003). In addition, since one potential benefit of reducing variety is the substitution of healthier LED foods for less healthy HED foods, behavioral economics may provide insight into how to structure environments to maximize (Epstein & Saelens, 2000) treatment effects. Reducing variety may also be considered a nudge toward better behavior, and research on how nudges can be used to facilitate behavior change (Thaler & Sunstein, 2008) may provide insight into how people can make healthier food choices when variety of less healthy foods is modified. Understanding the basic mechanisms for stimulus equivalence and how to implement ways to alter food variety represent important research directions for obesity treatment and prevention.

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