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Taste and food reinforcement in non-overweight youth

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Abstract

Food reinforcement is related to increased energy intake, cross-sectionally related to obesity and prospectively related to weight gain in children, adolescents and adults. There is very limited research on how different characteristics of food are related to food reinforcement, and none on how foods from different taste categories (sweet, savory, salty) are related to food reinforcement. We tested differences in food reinforcement for favorite foods in these categories and used a reinforcing value questionnaire to assess how food reinforcement was related to energy intake in 198 non-overweight 8–12 year-old children. Results showed stronger food reinforcement for sweet foods in comparison to savory or salty foods. In multiple regression models, controlling for child sex, minority status and age, average reinforcing value was related to total energy and fat intake, and reinforcing value of savory foods was related to total energy and fat intake. Factor analysis showed one factor, the motivation to eat, rather than separate factors based on different taste categories. Liking ratings were unrelated to total energy intake. These results suggest that while there are differences in the reinforcing value of food by taste groups, there are not strong differences in the relationship between reinforcing value of food by taste groups and energy or macronutrient intake.

Keywords

Taste; food reinforcement; energy intake; children; Reinforcing value; liking

Food reinforcement provides an index of the motivation to eat (Epstein, Leidy, Temple, & Faith, 2007). The reinforcing value of food has been cross-sectionally related to energy intake and obesity (Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008), and prospectively

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related to body fat and weight gain in children (Hill, Saxton, Webber, Blundell, & Wardle, 2009), adolescents (Epstein, Yokum, Feda, & Stice, 2014), and adults (Carr, Lin, Fletcher, & Epstein, 2014). Reinforcing value of food paradigms usually assess a person's favorite food, and there has been very little research on characteristics of food that may drive the motivation to eat. In a previous study with humans, reinforcing value of food was most strongly related to sugar intake (Epstein, Carr, Lin, & Fletcher, 2011), but this study did not assess reinforcing value for different types of food. Previous studies have examined differential effects of repeated consumption of high and low energy dense foods on food reinforcement of high and low energy dense foods (Clark, Dewey, & Temple, 2010). Women with higher, but not lower BMI showed an increase in food reinforcement after repeatedly consuming higher energy dense foods. Repeated consumption of lower energy density foods reduced food reinforcement for all women. Another approach to categorizing food is by basic types of taste: salty, sweet, umami (savory), bitter and sour. To date, no studies have determined if the reinforcing value of food varies as a function of taste properties.

While reinforcing value of a favorite food has been related to energy intake in the laboratory and natural environment (Epstein et al., 2011), there is no research on how reinforcing value driven by different tastes would relate to total energy intake, or energy intake of specific macronutrients. It is possible that reinforcing value of a specific taste would relate to total energy intake, or only to intake of specific macronutrients. Reinforcing value of sweet foods may be related to sugar intake, or reinforcing value of savory foods to fat intake.

Another commonly studied determinant of eating is food liking or hedonic ratings of food (Drewnowski & Hann, 1999; Finlayson, King, & Blundell, 2007). Although foods that are highly liked are often found to be highly reinforcing as well, the incentive salience theory of addiction argues that liking and wanting are separate processes that may differentially relate to consumption (Robinson & Berridge, 2004). This theory was originally developed to understand drug addiction, but it has been extended to natural rewards, such as food (Kelley & Berridge, 2002). Liking and wanting have been shown to differentially influence factors that regulate eating in animal studies (Berridge, 1996; Kelley & Berridge, 2002), and human studies suggest that factors that influence the motivation to eat differentially influence liking (Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003). Previous studies have shown that food reinforcement is a stronger predictor of energy intake than is liking (Epstein et al., 2011; Temple et al., 2008), but these studies have only studied one favorite food.

The goal of this study is to assess reinforcing value and liking of sweet, salty and savory (umami) foods and relate reinforcing value and liking to total energy and macronutrient intake in a large sample of non-overweight 8–12 year-old children. While sour and bitter are two additional basic tastes, children do not often choose to consume bitter or sour foods (Birch, 1999), and so we limited this study to basic tastes that more commonly drive food intake. This research will provide the first examination of how foods that vary in taste may differentially relate to food reinforcement, and how measures of food reinforcement relate to energy and macronutrient consumption. Studying foods from multiple taste categories provides the opportunity to assess whether the reinforcing value of salty, savory and sweet foods are uniquely related to energy and macronutrient intake, or whether there are one or

two factors that describe the relationship between food reinforcement and intake. Based on previous research (Epstein et al., 2011) we hypothesize that responding will be greatest for sweet foods, reinforcing value will be related to energy and macronutrient intake, and that reinforcing value will be a stronger predictor of intake than liking (Epstein et al., 2011; Temple et al., 2008).

Methods

Participants and Design

The participants were 198 (101 female and 97 male) non-overweight children 8–12 years old. The current study uses baseline data from a prospective study designed to examine individual differences in habituation of behavioral responding for food as risk factors for zBMI (standardized Body Mass Index) changes over a two year period in 231 healthy 8 to 12 year-old non-overweight children. Children were not included if they did not respond for the food in at least one of the taste groups, suggesting they did not find any of the foods in that category to be reinforcing ($N = 33$). The average characteristics of participants were 10.5 ± 1.4 years of age, zBMI of -0.08 ± 0.74 , and 31.0% minority. Percentage of children identified by their parents in different minority groups included 6.7% Hispanic, 2% as Asian, 13.3% as African American, and 10.3% as multirace. The average parental education was 15.8 ± 2.0 years.

Children who were not overweight, but at risk for becoming overweight were recruited if they were between the 50th BMI percentile and the 85th BMI percentile or if they were below the 50th BMI percentile, but had at least one parent with a current BMI ≥ 25 kg/m² (Magarey, Daniels, Boulton, & Cockington, 2003; Nader et al., 2006). Children also had to report at least a moderate liking (6 or greater on a 10-point Likert-type scale) for the study foods, and be at a second grade reading level based on the Wide Range Achievement Test (WRAT) (Wilkinson, 1993). Exclusionary criteria included 1) dietary restrictions that could interfere with the experiments, including food allergies or religious or ethnic practices that limit food choice or medical conditions which alter nutritional status or intestinal absorption, 2) activity restrictions due to medical or physical problems, such as uncontrolled exercise induced asthma or a disability requiring wheelchair; 3) psychopathology (e.g. childhood schizophrenia) or developmental disabilities; or 4) medications that could affect their level of activity or appetite (e.g. methylphenidate).

Procedures

Families were screened by phone and, if eligible, children were scheduled for four visits to the laboratory lasting approximately 120 minutes. Participants were instructed to refrain from eating and drinking anything except for water in the 3 hours prior to the test sessions and they were also instructed not to eat any of the study foods 24 hours before the test sessions. During the first visit to the laboratory the parents and children signed consent and assent forms, the child (with the help of the parent) completed a same-day food recall, the child and parent had their height and weight measured and the parents filled out demographic and medical questionnaires. The children picked their favorite salty food [Wheat Thins (Wheat thins snacks, original, Mondelez Global LLC., East Hanover, NJ),

pretzels (Wegmans Party Pretzels, Wegmans Food Markets Inc., Rochester, NY), tortilla chips (Tostitos Tortilla chips, crispy rounds, Frito-Lay Inc., Plano, TX), Fritos (Fritos Corn Chips, original, Frito-Lay Inc)], savory (umami) food [cheddar cheese (Wegmans cheese sticks, cheddar, Wegmans Food Markets Inc.), Goldfish (Goldfish crackers, baked snack, cheddar, Pepperidge Farm Inc., Norwalk, CT), pepperoni (Wegmans Sliced Pepperoni, Italian Style, Wegmans Food Markets Inc.), bologna (Oscar Meyer Bologna, Beef, Kraft Foods Group Inc., Northfield, IL)], and sweet food [chocolate chip cookies (Mini chips ahoy! Chocolate chip cookies, Mondelez Global LLC), Oreos (Mini Oreo cookie sandwiches, Mondelez Global LLC), Honey Buns (Little Debbie Honey Buns, McKee Foods, Collegedale, TN), Twizzlers (Twizzlers twists, strawberry, Hershey Company, Hershey, PA)] and they needed to report at least a moderate liking (6 or greater on a 10-point Likert-type scale) of their favorite foods. Foods were placed in these categories if 1) 25% or more of the kilocalories from the snack was from sugar (sweet), 2) the presences of an umami flavor (eg. Meats, tomato, and cheeses) (savory), or 3) the presence of sodium (>120 mg a serving)(salty) with less than 15% of the snack from sugar and no presence of umami flavor.

During the first laboratory session the reinforcing value of food (salty, savory, and sweet foods) was measured using a validated questionnaire (Goldfield, Epstein, Davidson, & Saad, 2005), with foods presented in random order. Dietary awareness was also measured in the first session. Energy and macronutrient intake was measured during sessions 2–4. Behavioral habituation, executive function, physical activity, reading level, and food neophobia were measured but not reported here. At the end of the sessions, participants were compensated \$80.00 US dollars gift cards for completing the four sessions. All procedures were conducted in accordance with guidelines for the ethical conduct of human research and with the approval of the University at Buffalo Social and Behavioral Sciences Institutional Review Board.

Measures

Demographics—A general demographics questionnaire was used to assess education, annual income, and race. Years of education were coded separately for fathers and mothers, and the highest level of education was used as the family education. Children were coded as minority or non-minority (Caucasian).

Anthropometrics—Weight was assessed by a digital scale (TANITA Corporation of America Inc, Arlington Heights, IL) and height using a digital stadiometer (Measurement Concepts & Quick Medical, North Bend, WA). Body mass index (BMI) was calculated according to the formula: $BMI = kg/m^2$. BMI percentile values were standardized for the child's age and sex, so that BMI percentile values of 50 represent the midpoint of the distribution (Percent OverBMI), and zBMI scores were standardized based on child age and sex (Kuczmarski et al., 2002).

Same-day food recall—To ensure compliance with the protocol (not eating or drinking anything other than water for three hours prior to testing), the child (with the help of parent) recalled dietary intake for that day.

Subjective ratings of hunger and fullness and food liking—Initial food liking of all study foods were asked on a 10 point likert-type scale anchored by “Do not like” and “Like very much”. Subjective ratings of hunger were obtained prior to engaging in the reinforcing value of food task on a 5 point likert-type scales anchored by extremely hungry and extremely full.

Reinforcing value of food—The Reinforcing Value of Food Questionnaire was used to assess motivation to eat each of the favorite sweet, savory and salty foods (25g portions) versus an alternative activity, five minutes of access to magazines and activity puzzles/word searches. The task was experimenter administered, in that the experimenter asked the child whether they preferred the food or alternative activity for each choice. This method has been validated against the standard concurrent schedule laboratory measure of relative reinforcing value (Goldfield et al., 2005), and previously used in 7–12 year old children (Epstein, Dearing, Temple, & Cavanaugh, 2008; Hill et al., 2009). The child was presented with 15 choices, in which the work required for food increased from 20 to 600 clicks on a hand counter and the work required for the alternative activity stayed at 20 responses (clicks on a hand held golf counter). The child was asked to indicate their preference for each question, and the schedule stopped when the child had chosen the activity for two consecutive choices. The child was first instructed on the task and given several examples and a practice trial. To ensure the children made realistic choices, at the end of the questionnaires, the child chose a chip out of a bowl and was required to complete the choice they made for that schedule and was given 25 grams of food or allowed 5 minutes to use the activities. The order of the three foods was randomized. The reinforcing value of food was defined as the schedule at which the child switched to activity for two consecutive choices.

Energy and macronutrient intake—Twenty-four hour dietary intake was measured three times using the National Cancer Institute’s Automated Self-Administered 24 hour recall program (ASA24). The ASA24 uses a multi pass method to gather information related to an individual’s intake (Subar et al., 2012; Zimmerman et al., 2009). Dietary intake was assessed with an experimenter and parent present to help the children complete the dietary recall (Baranowski et al., 2012). Automated multiple pass methods, including ASA24, to collect energy intake have been validated in children when an adult is present to aid with the recall (Baranowski et al., 2012).

Dietary awareness—The Dutch Eating Behavior Questionnaire revised for children ages 8–12 was used to measure dietary awareness. This questionnaire provides three scales, emotional eating, dietary disinhibition, and restrained eating (van Strien & Oosterveld, 2008).

Reading and mathematical level—The Wide Range Achievement Test (WRAT) was used to assess reading level, and numeracy in the children. This is a widely used, well validated method to assess reading and mathematical level of achievement (Wilkinson, 1993). Data are presented in terms of standardized reading and mathematical scores.

Analytic Plan

Data screening was conducted prior to statistical analysis to identify outliers and examine variable distributions for normality. Two-way mixed analysis of variance with food type as the within factor and order of food presentation as a between factor was used to test for differences in reinforcing value or liking of sweet, savory and salty foods. Linear contrasts were used to assess post-hoc differences. Effect sizes for the ANOVAS were established using partial eta-squared. Zero-order relationships were established between predictors of energy intake and measures of reinforcing value and liking. Differences between correlation coefficients predicting energy and macronutrient intake from measures of food reinforcement were assessed using the Fisher r-to-z transformation for dependent samples (Bruning & Kintz, 1977). Multiple regression was used in models to predict energy or macronutrient intake with food reinforcement as a predictor, controlling for sex, age and child minority status, variables that were related to energy and macronutrient intake. A principal components factor analysis for the three measures of food reinforcement was done using SAS (SAS Institute Inc., 2004). The number of factors to be extracted was determined based on eigenvalues, a scree plot and parallel analysis. Item loading was examined for loading greater than 0.35. All data were reported as mean $\pm$ SD. Data were analyzed using SYSTAT 11 (Systat Software, 2004) and SAS (SAS Institute Inc., 2004). One outlier was removed from the regression models.

Examination of the reinforcing value distributions by taste categories showed a significant positive skewness and excess kurtosis for each set of values (D'Agostino & Stephens, 1986). Values were log transformed to improve normality of the distribution, and analyses were completed using both the raw and log transformed data. No differences in the overall pattern of results were observed whether raw or log transformed data were used, so the data presented were based on the analyses of raw data to facilitate interpretation of the data.

Results

Baseline characteristics of children are presented in Table 1. Significant differences in reinforcing value by taste grouping was observed ($F(2,382) = 9.16, p < 0.001$), with no effect of order on reinforcing value ($p = 0.21$). As shown in Figure 1A, reinforcing value of sweet foods was greater than savory ($p = 0.013$) and salty ($p = 0.009$) foods, with a trend towards differences between savory and salty foods ($p = 0.053$). Significant differences also were observed in liking for the child's favorite foods (Figure 1B) by taste categories ($F(2,382) = 15.50, p < 0.001$), with no effect of order on liking ($p = 0.14$). Figure 1C shows number of participants who responded at each schedule across taste groupings. Sweet foods were liked more than savory and salty foods ($p < 0.001$), with no differences in liking between savory and salty foods ($p > 0.05$). The partial eta squared effect sizes showed that differences in reinforcing value across food types accounted for 4.6% of the variance in reinforcing value ratings, while the differences in liking across food types accounted for 7.5% of the variance in liking ratings.

Table 1 shows zero order predictors of total energy intake as assessed by the repeated 24 hour recalls, as well as carbohydrate, fat, protein and sugar intake. Results showed child sex ($r = -0.18, p = 0.013$, with boys consuming more than girls), child age ($r = 0.16, p = 0.026$,

with older children consuming more than younger children), and minority status ($r = -0.14$, $p = 0.045$, with non-minority children consuming more than minority children) predicted total energy intake. Child sex also predicted protein ($r = -0.26$, $p < 0.001$), carbohydrate ($r = -0.16$, $p = 0.022$) and sugar ($r = -0.15$, $p = 0.03$). Minority status predicted carbohydrate ($r = -0.18$, $p = 0.009$) and sugar intake ($r = -0.18$, $p = 0.013$). Age was related to carbohydrate ($r = 0.14$, $p = 0.046$), protein ($r = 0.15$, $p = 0.036$) and sugar intake ($r = 0.19$, $p = 0.009$). Age and weight were strongly related ($r = 0.79$, $p < 0.001$), and weight was related to total energy ($r = 0.20$, $p = 0.005$), carbohydrate ($r = 0.17$, $p = 0.014$), fat ($r = 0.16$, $p = 0.027$), protein ($r = 0.23$, $p = 0.001$) and sugar intake ($r = 0.18$, $p = 0.011$).

Average food reinforcement predicted total energy ($r = 0.17$, $p = 0.015$), fat ($r = 0.19$, $p = 0.009$) and protein ($r = 0.16$, $p = 0.028$) intake. Reinforcing value of salty foods ($r = 0.15$, $p = 0.042$) was related to fat intake, reinforcing value of savory foods predicted total energy ($r = 0.18$, $p = 0.01$), fat ($r = 0.20$, $p = 0.006$) and protein ($r = 0.15$, $p = 0.04$). Reinforcing value of sweet foods did not predict energy or macronutrient intake. Average liking ratings of savory foods (not liking ratings of the favorite savory food) was related to protein ($r = 0.17$, $p = 0.019$) intake. None of the liking ratings of favorite foods were related to energy or macronutrient intake.

Regression models controlling for child gender, age and minority status showed average reinforcing value was related to total energy ($B = 0.062$, $p = 0.032$) and fat intake ($B = 0.034$, $p = 0.015$), and reinforcing value of savory foods was related to total energy ($B = 0.60$, $p = 0.016$) and fat intake ($B = 0.032$, $p = 0.008$). The other relationships for average reinforcing value, and reinforcing value of salty and savory foods were not significant controlling for sex, age and minority status. Similarly, the relationship between liking of savory foods and protein intake was no longer significant after controlling for sex, age and minority status.

The reinforcing value of food was generally not related to liking of food. The relationship between reinforcing value and liking of favorite food was significant for salty foods ($r = 0.17$, $p = 0.017$), but was not related for savory ($r = -0.007$) or sweet ($r = 0.12$) or average liking rating and average reinforcing value ($r = 0.08$). When the average liking ratings for all foods in the food type were considered, the relationships with reinforcing value were (r 's = 0.06 , -0.04 , 0.00 – 0.02 , p 's > 0.05) for salty, savory, sweet and average ratings, respectively. In addition, the reinforcing value of food was not related to energy density for salty ($r = 0.087$), savory ($r = -0.11$) or sweet ($r = -0.03$, p 's > 0.05) foods.

For the principal components factor analysis, the eigenvalues, scree plot and parallel analysis indicated that one factor should be extracted. There was only one eigenvalue greater than one using the Kaiser-Guttman rule (eigenvalue, 2.18), and the scree plot included an elbow at 1 factor. This factor accounts for approximately 72.7 percent of the variance. The loadings for each of the reinforcement values were all greater than 0.82 (sweet 0.82; savory 0.88; salty 0.86), indicating one general food reinforcement factor. The three measures of food reinforcement are highly correlated, with savory correlating $r = 0.65$ and $r = 0.58$ (p 's < 0.001) with salty and sweet foods, and the reinforcing value of salty and sweet foods were correlated ($r = 0.54$, $p < 0.001$). This suggests that while there were some differences

between reinforcing value for different types of food and energy and macronutrient intake, the data may be better characterized as representing a general measure of the motivation to eat. When the degree of relationship was tested comparing correlation coefficients for each type of food across energy intake and macronutrient intake, there were no significant differences between the degrees of relationship (p 's > 0.35). Thus, reinforcing value of savory foods was related to total energy intake, but there were no differences in the degree of relationship between savory, salty or sweet foods as predictors of total energy intake.

Discussion

Food is a powerful reinforcer that motivates people to eat. Very little is known about characteristics of foods that are related to differences in food reinforcement. This study shows that non-overweight children find foods that taste sweet the most reinforcing, and will work harder to get these foods than foods that are salty or savory. This research is consistent with animal research showing that sugar is reinforcing (Avena, Long, & Hoebel, 2005; Avena, Rada, & Hoebel, 2008). In addition to the reinforcing value of sugar in animal models, sugar intake also sensitizes the reinforcing value of drugs (Avena, Carrillo, Needham, Leibowitz, & Hoebel, 2004; Avena & Hoebel, 2003; Colantuoni et al., 2002), and sugar activates dopaminergic release (Rada, Avena, & Hoebel, 2005). In humans, the reinforcing value of food has been related to energy intake from sugar (Epstein et al., 2011), and sugar is related to greater activation of reward and gustatory regions than dietary fat (Stice, Burger, & Yokum, 2013).

While significant differences in reinforcing value were observed for favorite foods in different taste categories, it may be better to consider reinforcing value of favorite foods to be one factor as they relate to energy or macronutrient composition, rather than three separate factors. This is because there is considerable correlation between reinforcing value of the three types of food and there were minimal differences in the magnitude of the relationships between different aspects of food reinforcement and energy and macronutrient intake. The effect size comparing differences between the types of food reinforcement accounted for less than five percent of the variance, and a factor analysis showed one factor best describes the data. This may be an artifact of the types of foods studied, and favorite foods among the food types were being compared. In other words, all the foods were relatively reinforcing. There may have been larger differences if highly reinforcing foods were compared to less reinforcing foods, but this could occur within or between food groups. This interpretation does not detract from the finding of significant between group differences in reinforcing value between food types, but rather that the differences may not strongly impact energy or macronutrient intake.

This study provides another test of the differential relation between reinforcing value of food and food liking, with reinforcing value being a predictor of total energy intake while liking was not. This study extends previous research by assessing reinforcing value and liking for foods that fall in three different taste groups, and compares reinforcing value and liking for the favorite foods in each taste grouping. While reinforcing value is not interchangeable with wanting (Berridge & Robinson, 2003), reinforcing value is conceptually related to

wanting, providing additional support for differences in hedonic response and motivation to eat conceptualized in incentive salience theory (Robinson & Berridge, 2004).

There are limitations to be considered. First, the study only involved non-overweight youth. Given individual differences in food reinforcement for obese and non-obese youth (Temple et al., 2008), it is possible that obese youth may have different levels of food reinforcement across the taste groups. However, the study of only non-overweight youth provides an indication of the basic relationship between taste and food reinforcement, and food reinforcement and energy intake that does not depend on child weight. Second, only a limited array of foods from each taste group were studied, and foods within the taste group had different energy density and macronutrient composition. Thus, it is possible that factors that are associated with taste, rather than taste alone, influenced reinforcing value and the relationship with energy intake. Third, only solid foods were studied, and beverages, which can also differ in terms of taste characteristics, were not studied. This may be relevant since beverages may be less satiating than solid foods, and sugar sweetened beverages are highly reinforcing (Temple, Bulkley, Briatico, & Dewey, 2009).

Providing the same amount (25g) of different types of reinforcers in comparison to the same alternative behavior provides the opportunity to get an estimate of substitutability of the reinforcers. The pattern of results show that among the foods available, salty and savory foods may be substitutes for each other, but salty or savory foods may be less substitutable for sweet foods. A way to test substitutability of salty or savory foods for sweet foods in laboratory assessments of reinforcing value is to directly compare responding for the two types of foods, and assess how much extra response demands (constraint on access) are needed to shift preference (Goldfield & Epstein, 2002). This would be accomplished in the laboratory by keeping schedules for one type of food (savory) constant, and varying the schedules for access to sweets. Based on the pattern of responding for food versus alternatives, it is assumed that many children would work harder for sweet than savory foods. The amount of increase in responding needed to equate reinforcing value indexes the degree of substitutability (Bickel, Marsch, & Carroll, 2000). For example, if two participants differ in how much extra responding is needed to shift preference from sweet to savory foods, then the participant who shifts after a smaller increment in response requirements would find savory foods more substitutable. This provides valuable data that can be used to develop intervention programs for behavior change.

If access and consumption of each type of food differs across children, an indifference point in which children have no preference for a particular type of food versus another type of food may not involve the same amount of each type of food. Consider someone who regularly drank three glasses of milk a day and one soda. It is tempting to infer that milk is more reinforcing than soda because they drank three glasses, compared to one glass of soda. When comparing the reinforcing value of milk and soda the experimenter has the choice of using the same amount of each type of food, or use different amounts based on pre-experiment equivalence testing (Bickel, DeGrandpre, Higgins, & Hughes, 1990; Bickel et al., 2000). It is also possible that the same amount of a sedentary behavior may not be equivalent to all foods, and since the questionnaire assessed relative reinforcing value, the relative amounts of food may have been different for comparison to the non-food

alternative. This intriguing possibility requires research on the substitutability of reinforcers, which would provide an index of how much of each type of reinforcer should be provided to equate them.

Additional research is needed to move beyond demonstrating that food reinforcement is an important factor in eating and obesity to studying what properties of food drive excess food reinforcement and excess energy intake in obesity. This may lead to new and innovative approaches to modifying eating behavior and preventing or treating pediatric obesity.

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Highlights

- Food reinforcement is related to energy intake, weight gain and obesity
- There is no research on major taste groups and food reinforcement
- Sweet foods were the most reinforcing
- Food reinforcement was related to energy intake
- Food reinforcement was a stronger predictor of energy intake than liking

Figure 1. Relative reinforcing value (schedule switchpoint, Figure 1A) and liking (Figure 1B, mean $\pm$ SD) and the number of children who continued to respond for each schedule of the reinforcing value questionnaire (Figure 1C) for children provided foods from sweet, savory and salty food groups. Analysis of variance showed differences in reinforcing value by food groups ($p < 0.001$), with reinforcing value of sweet foods greater than savory ($p = 0.01$) and salty ($p < 0.001$) foods. Significant differences also were observed in liking by taste categories ($p < 0.001$), with sweet foods liked more than salty and savory foods ($p < 0.001$).

Subject characteristics and correlational relationship between each predictor and energy and macronutrient intake derived from three day food record dietary intake

Table 1

Characteristics	Mean	SD	Three day food record calories				
			Total	Carbo	Fat	Protein	Sugar
			r	r	r	r	r
Sex (F/M)	100/97		-0.18*	-0.17*	-0.09	-0.26***	-0.15*
Age (years)	10.47	1.42	0.16*	0.14*	0.13	0.15*	0.19**
% Minority (non/min) ¹	136/61		-0.14*	-0.18**	-0.10	-0.02	-0.18*
Parental ed (years) ²	15.81	1.96	0.05	0.07	0.03	-0.02	0.02
zBMI	-0.08	0.74	0.12	0.06	0.12	0.22**	0.01
Wt (lbs)	77.96	18.24	0.20**	0.17*	0.16*	0.23**	0.18*
Percent OverBMI	0.22	8.91	0.12	0.07	0.12	0.19**	0.02
Wide Range Achievement TEST (WRAT)							
Reading	109.08	11.28	-0.04	0.01	-0.08	-0.03	-0.03
Mathematics	110.80	12.70	0.06	0.04	0.05	0.06	0.00
Dutch Eating Behavior Questionnaire							
Emotional eating	1.36	0.41	0.05	0.06	0.03	0.05	0.10
Disinhibition	2.26	0.41	0.10	0.13	0.08	0.01	0.13
Dietary restraint	1.59	0.42	-0.08	-0.08	-0.08	-0.02	-0.03
Relative reinforcing value ³							
Average	130.68	117.02	0.17*	0.12	0.19**	0.16*	0.11
Salty foods	113.05	124.04	0.13	0.08	0.15*	0.11	0.09
Savory foods	127.21	133.29	0.18*	0.13	0.20**	0.15*	0.08
Sweet foods	151.78	154.86	0.13	0.10	0.13	0.14	0.12
Liking – All foods in food type							
Average	7.20	1.23	0.07	0.05	0.05	0.14	0.09
Salty foods	7.41	1.60	0.05	0.02	0.07	0.07	0.05
Savory foods	6.73	1.77	0.10	0.09	0.06	0.17*	0.11

Characteristics	Mean	SD	Three day food record calories							
			Total	Carbo	Fat	Protein	Sugar	r	r	r
Sweet foods	7.45	1.50	-0.02	-0.01	-0.04	0.05	0.04			
Liking – Favorite food in food type										
Average	9.20	0.83	0.10	0.06	0.12	0.11	0.05			
Salty	8.99	1.26	0.07	0.01	0.11	0.09	0.02			
Savory	9.10	1.26	0.10	0.08	0.10	0.09	0.09			
Sweet	9.50	0.89	0.04	0.03	0.04	0.04	0.00			
Hunger ⁴	2.21	0.87	-0.08	-0.04	-0.09	-0.10	-0.04			
Three day dietary recall										
Total Calories	1825.38	483.25								
Carbohydrate (g)	243.32	67.23	0.90***							
Fat (g)	68.56	22.79	0.89***	0.64***						
Protein (g)	64.42	20.61	0.77***	0.55***	0.70***					
Sugar (g)	113.97	41.70	0.74***	0.87***	0.48***	0.44***				

Note

¹ % minority refers to the percent of families who are not Caucasian,² parental education is highest parental education.³ The reinforcing value of food was defined as the schedule at which the child switched to activity for two consecutive choices.⁴ Hunger represents ratings obtained prior to the reinforcing value questionnaire.

* p < 0.05

** p < 0.01

*** p < 0.001