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Overweight children habituate slower than non-overweight children to food

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Abstract

We have shown that physiological and behavioral responses habituate to food stimuli and recover when novel stimuli are presented. In addition, physiological responses in obese adults habituate slower to repeated food stimuli than non-obese individuals, which is related to greater energy intake. The purpose of this study was to test the hypothesis that instrumental responding in overweight children habituates slower to food cues than in their non-overweight peers. Children were provided the opportunity to work for access to cheeseburger for 10 2-min trials, followed by French fries for 3 2-min trials. Results showed that children who had a body mass index (BMI) at or above the 85th BMI percentile (at risk for overweight; $n = 17$) habituated slower than those with a BMI percentile less than the 85th BMI percentile (non-overweight; $n = 17$). Response recovery to French fries did not differ between groups. Overweight children consumed significantly more grams of food and more energy than non-overweight children. When taken together, these data show that habituation may be an important individual difference characteristic that differentiates overweight from non-overweight children. Implications of this for prevention and treatment of obesity are discussed.

Keywords

Habituation; obesity; children; operant responding; body mass index

Habituation is a basic property of the nervous system, whereby physiological and behavioral responses decrease after successive presentations of the same stimulus and increase with exposure to a novel stimulus [1]. Both children and adults show response habituation after successive presentations of the same food, which recover when a novel food is presented [2–6]. The rate of habituation is related to energy consumption, such that individuals who display slower rates of habituation also consume more energy [7]. In addition, stimuli which disrupt habituation also increase energy intake. For example, the rate of habituation is decreased by exposure to food variety [5,8] and food variety increases food intake during laboratory eating tasks [9,10]. Distracting stimuli, such as television [11] and audiobooks [12] also disrupt habituation to food cues and increase energy intake [11]. When taken together, these data suggest that satiety and the cessation of eating are related, in part, to habituation to food stimuli.

Habituation was initially studied in the context of reflexive physiological responses, but more recent theoretical work has applied habituation theory to instrumental responding [13]. For

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example, a study by Melville and colleagues showed that instrumental responding for food decreased over time, but was reinstated when a novel food was presented [14]. In addition, this study showed that the rate of within session changes in instrumental responding was contingent on the magnitude of the reinforcer [14]. When taken together, these studies show that habituation not only occurs for reflexive, physiological responses, but applies to complex, behavioral responses as well.

We have shown that obese adults show slower salivary habituation than non-obese adults [15]. The purpose of the present study was to determine if overweight children show slower habituation of instrumental responding for food than non-overweight children. Therefore, this study will expand our knowledge of the influence of overweight on habituation in children and provide information on habituation using a more complex behavioral paradigm.

METHODS

Participants

Participants were 18 females and 16 males *age* 8–10 recruited from a pre-existing database and a direct mailing. The average participant was 9.6 ± 0.79 years of age, had a BMI of 20.3 ± 4.8 (BMI = kg/m²), and was at the 67.8 ± 34.1 for BMI percentile (Table 1). The majority of the participants' parents completed college (67.6%) and had a household income of greater than \$30,000 per year (58.8%). The sample included 58.8% non-Hispanic Caucasian, 23.5% African American 11.8% Hispanic, 2.9% Asian, and 2.9% mixed race (African American and non-Hispanic Caucasian) children. There were no differences between the groups in age, parental education, household income, same-day food intake, food liking, or percentage of minority participants ($p > 0.05$ for all). The overweight group had a significantly higher dietary restraint score than the non-overweight group ($t = 2.38$, $p = 0.02$; Table 1). Exclusionary criteria for the experiment were: any obesity related chronic diseases (i.e., diabetes), any developmental or psychological disabilities that may impair participant's ability to complete the experiment; any medications such as methylphenidate that may modify appetite, prior participation in a laboratory study using similar methodology. In addition, all participants needed to report at least a moderate liking (≥ 3 on a 5-point Likert-type scale) of the food stimuli presented in the experiment.

Procedures

The parents of the participants were screened by telephone to ensure that the child met the above criteria. Eligible participants were scheduled for one 60-minute visit to the University at Buffalo's Behavioral Medicine Laboratory on a weekday between the hours of 2:00 and 5:30 pm. Parents were instructed to have their children eat their normal breakfast and lunch, but to not eat or drink anything (except water) three hours prior and not to consume the study foods 24 hours prior to the visit. Upon arrival to the laboratory, both parents and children completed consent and assent forms along with a same-day food recall for the child. Parents then filled out a demographic form while the child filled out food liking, hunger and food preference questionnaires. After forms were completed, the parents were escorted to the waiting area and the experimental task commenced. After the experimental task, participants filled out both a hunger scale and a Dutch Eating Behavior Questionnaire adapted for children [16] which assesses dietary restraint. Height and weight were then obtained using the procedures outlined below. Finally, both parent and child were debriefed about the purpose of the study and given written materials about the theoretical rationale behind the experiment. Participants were compensated \$20.00 US dollars for completing the experiment. 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 Health Sciences Institutional Review Board.

Habituation Task—The task was divided into habituation and recovery phases. The habituation phase was 20 minutes, divided into 10, 2-minute trials, during which participants could earn points towards access to 100 kcal (40 g) portions of a Wendy's® Jr. Cheeseburger. The recovery phase lasted for six minutes, divided into 32-minute trials, during which participants had the opportunity to earn points towards 100 Kcal (37 g) portions of Wendy's® french fries. Participants received the food immediately after each point was earned and could continue to play the computer task while eating. Water was provided ad libitum throughout the duration of the experiment.

Laboratory Environment

The laboratory was specially constructed for eating experiments and is equipped with an air delivery system that circulates new air through each room approximately 10 times per hour. The experiment rooms are also constructed with intercom systems so that the participant could communicate with the experimenter throughout the duration of the experiment.

Measures

Instrumental Responding—A computer generated task was used to measure instrumental responding for food. It was programmed at a variable interval 120 ± 30 seconds (VI-120) reinforcement schedule. The computer task consisted of two squares, one that flashed red every time a mouse button is pressed and another square that flashed green when a point was earned. Participants were rewarded one point for the first response made after approximately 120s had passed and were reinforced with a 100 kcal portion of food at that time. Participants were instructed that when they no longer wanted to earn access to the food stimulus they could go another table and engage in the activities provided. Activities included age appropriate puzzles, crosswords, word searches, and magazines. Participants were also told that they could move freely between the computer and activity stations. The primary outcome measures were the number of responses made for food during each 2-minute interval and the amount of food and energy consumed.

Food Hedonics & Hunger—Liking of study foods was assessed by 5-point Likert-scales, anchored by one “Do not like” and by five “Like very much”. A 40-item food questionnaire which included the study foods was also administered to ensure reliability of reported liking of study foods. Hunger was measured at the beginning and end of each session, and assessed on a 5-point Likert-scale, anchored by one “Not very hungry” and by five “Extremely hungry”.

Same-day Food Recall—Same-day food recalls were conducted as an interview with both the child and parent present. The energy consumed was calculated by Nutritionist V nutrient analysis software [17]. This measure was included to verify adherence to the study protocol by ensuring that the participant had not consumed food or drink (except water) in the three hours prior to the appointment and that they had not consumed the study foods that day.

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

Anthropometrics—Height (cm) and weight (lb) were measured *without shoes in light clothing after the participant had voided* using a Digi-Kit™ digital stadiometer and a Tanita™ digital weight scale. These measurements were then used to calculate BMI (kg/m^2). Children below the 85th BMI percentile were defined as non-overweight while children greater than or equal to the 85th BMI percentile were defined as at risk for overweight or overweight [18].

Dietary Restraint—The Dutch Eating Questionnaire revised for children ages 8–12 was utilized to measure dietary restraint [16]. Examples of questions asked on the DEBQ are “I

have tried to lose weight”; “I try not to eat between meals because I want to be thinner”. The median score on this questionnaire was 6.

Analytic Plan

Data were compared between participants who were non-overweight (< 85th BMI percentile; n=17) or at risk for overweight/overweight ($\geq$ 85th BMI percentile; n=17). Participant characteristics (ex. age, BMI percentile, etc), food liking, subjective hunger before and after the testing session, and self-reported same-day energy intake were compared using independent sample T-tests. Categorical variables, such as parental education, parental income, and percent minority were analyzed using Chi-Square. Responses to obtain food over trials were analyzed using a mixed, repeated measures analysis of covariance (ANCOVA) with weight status as the between subjects factor and trials as the within subjects factor. Two covariates were included in the ANCOVA, dietary restraint, which was significantly different between the groups, and responding on the first trial, since this variable is a predictor of the rate of change in habituation [13]. Amount of food (grams) and energy (Kcal) consumed during the testing session were analyzed using a one-way ANOVA with weight status as the between subject factor.

RESULTS

There was no effect of weight status on any of the following: age, subjective hunger before or after testing, food liking, self-reported same-day energy intake, percent minority, parental income, or parental education ($p > 0.05$; Table 1). There were differences by weight status for BMI percentile ($t = 8.52$; $p < 0.0001$) and in dietary restraint scores ($t = 2.38$; $p = 0.02$; Table 1).

There was a significant interaction of weight status by trials 1 – 13 ($F(12, 360) = 1.82$, $p = 0.04$; Figure 1). In order to determine whether the interaction of weight status and trials was specific to one of the experimental phases, habituation (trials 1 – 10) or recovery (trials 11 – 13), the two phases were subsequently analyzed separately. This analysis revealed that the interaction of weight status and trials was restricted to the habituation phase of the experiment ($F(9, 270) = 2.02$, $p = 0.04$) with no interaction of weight status and trials 11 – 13 ($F(2, 60) = 1.92$, $p = 0.16$).

Overweight children consumed significantly more grams of food (Mean $\pm$ SEM = 392.1 ± 28.2 vs. 314.8 ± 21.4 , respectively; $F(1, 32) = 4.79$, $p = 0.04$, data not shown) and more energy ($F(1, 32) = 6.04$, $p = 0.02$; Figure 2) than non-overweight children.

DISCUSSION

This study demonstrates that overweight children habituate at a slower rate to food cues than non-overweight children, with no differences in the rate of recovery to novel food cues. This study replicates and extends our previous findings from adults [15] to children using an instrumental behavior task. Overweight children also consumed more energy than their non-overweight peers. These data suggest that by 8 – 10 years-of-age weight status is associated with the rate of habituation to food cues and energy intake.

The observation that instrumental responding habituated, as shown by the decrease in responding after repeated presentations and the recovery of responding after presentation of a new food, is consistent with other research from this laboratory [19] and the theoretical work of McSweeney and colleagues, who argue that the decrease in within-session instrumental responding for a reinforcer after repeated presentations is due to habituation [13,20]. The application of habituation theory to instrumental responding was initially developed in animal

models using food as the reinforcer, but has been extended to changes in physical activity [21] and more recently to theoretical approaches to alcohol consumption [20].

The recovery of responding after presentation of a new food suggests that the reduction in responding after repeated presentation of food is not due energy repletion or to a change in energy homeostasis. Rather, a change in the sensory qualities of a new palatable food is a more likely mechanism [19]. Habituation paradigms have shown that responding for food and energy intake are reinstated when a novel food stimulus is presented, even when the individuals report that they feel full [6]. This decrement of instrumental responding for the same food and recovery of responding for a novel food is consistent with sensory-specific satiety, which shows that the hedonic value of a food decreases after being eaten to satiety, while the hedonic value of an uneaten food remains the same [22–23]. When taken together, both habituation and sensory specific satiety theories suggest that the cues used to determine initiation and cessation of eating are related more to pleurability and novelty of the foods than to physiological indicators of satiety.

This study demonstrates that weight status relates to responding for food and energy intake in children as young as 8 years of age. The differences by weight status were limited to the habituation phase, as there were no group differences in responding when a new food was presented. This is not surprising, given that one of the principal criteria of habituation is that responses recover when a novel stimulus is presented. In fact, we have shown in several previous studies that presentation of a novel food leads to a recovery of responding that is equivalent to responding on the first trial [4,6,11]. We found the same results in the present study, with responses during the recovery phase equivalent to those at baseline in both groups. Therefore, because both groups are showing maximum responding for the novel stimulus, there is no opportunity to observe between group differences. Another consideration of this study is that the foods that were chosen, cheeseburger and french fries, are commonly consumed and considered very palatable. It is possible that the pattern of habituation and recovery would be different for other foods, and research is needed to examine instrumental responses over a range of foods that vary in their palatability and their macronutrient composition.

The rate of habituation to food may be important in the development of obesity. We have shown previously that food-related factors, such as dietary variety [24] and non-food related factors, such as attentional allocation [12] and television watching [11] disrupt habituation and increase energy intake. These same factors have been associated with obesity [25–29], most likely by mediating effects on energy intake [30–32]. This study established weight-related difference in the rate of habituation in children as young as 8 years of age. We do not know whether slower habituation precedes overweight or if chronic overeating alters habituation to food cues. Future studies should focus on investigating this question both by studying younger children who are not yet overweight to establish whether individual differences in habituation exist in this population, as well as by conducting longitudinal studies in children to determine if the rate of habituation is predictive of future overweight. If individual differences in the rate of habituation predict future overweight, than studying this individual difference variable may be a way to identify at-risk populations. Once these populations have been identified, strategies can be developed that minimize factors that disrupt habituation, such as variety [24] and distraction [11,12], and, thus, possibly reduce energy intake and prevent the development of obesity.

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Figure 1.

The mean $\pm$ SEM number of responses made on each trial for cheeseburger (trials 1 – 10) and French fries (trials 11 – 13) in children who are below the 85th BMI percentile (open circles) or at or above the 85th BMI percentile (filled circles). There was a significant group by time interaction for responses with the children at risk for overweight/overweight decreasing responding at a slower rate than the non-overweight children ($p = 0.04$).

Figure 2.

The mean $\pm$ SEM amount of energy (Kcal) consumed during the habituation task in children who are below the 85th BMI percentile (black bar) or at or above the 85th BMI percentile (white bar). Children at risk for overweight/overweight ($\geq$ 85th BMI percentile) consumed significantly more energy (Kcal) during the task as compared to non-overweight children ($p = 0.02$).

Table 1
Characteristics of participants in non-overweight and overweight conditions

Descriptive Variables	Group			
	Non-overweight		Overweight	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Number of Participants	17		17	
Age (years)	9.6	0.8	9.7	0.8
BMI Percentile *	39.8	27.1	95.8	2.0
Restraint Scores	4.5	3.7	7.1	2.4
Subjective Hunger Before	3.7	1.2	3.8	1.0
Subjective Hunger After	1.2	0.2	1.5	0.2
Cheeseburger Liking	4.5	0.5	4.3	0.8
French Fry Liking	4.3	0.8	4.4	0.8
Self-reported Energy (Kcal)	815.5	272.2	758.8	377.0
	<u>N</u>	<u>%</u>	<u>N</u>	<u>%</u>
Race				
Caucasian	10	58.8	10	58.8
African American	5	29.4	3	17.6
Hispanic	1	5.9	4	23.5
Other or multiracial	1	5.9	2	11.8
Parent's Income				
Under \$29,999	8	47.1	6	35.3
\$30,000 – \$59,999	8	47.1	9	52.9
≥ \$60,000	1	5.8	2	11.8
Parental Education				
High school/vocational	7	41.2	4	23.5
College or graduate degree	10	58.8	13	76.5

Note. BMI = body mass index (kg/m^2);

* $p < 0.05$ between groups.