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A questionnaire approach to measuring the relative reinforcing efficacy of snack foods

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Abstract

Behavioral choice theory and laboratory choice paradigms can provide a framework to understand the reinforcing efficacy or reinforcing value of food. Reinforcing efficacy is measured in the laboratory by assessing how much effort one will engage in to gain access to food as the amount of work progressively increases. However, this method to establish demand curves as estimates of reinforcer efficacy is time consuming and limits the number of reinforcers that can be tested. The general aim of this study was to compare the reinforcing efficacy of snack foods using a behavioral task that requires subjects to respond to gain access to portions of food (LAB task) with a questionnaire version of a purchasing task designed to determine demand curves (QUES task) in nonobese and obese adults ($n = 24$). Results showed correlations between the maximal amount of money that individuals were willing to spend for food (QUES O_{max}) and the maximal amount of responses made on the highest reinforcement schedule completed (LAB O_{max}) ($r = 0.45$, $p < 0.05$), and between BMI and the LAB O_{max} ($r = 0.43$, $p < 0.05$) and the QUES O_{max} ($r = 0.52$, $p < 0.05$). The study suggests the questionnaire provides valid measures of reinforcing efficacy that can be used in place of or in conjunction with traditional laboratory paradigms to establish demand curves that describe the behavioral maintaining properties of food.

Keywords

Reinforcement; Eating; Behavioral economics

Food is a powerful reinforcer, and developing a better understanding of the motivation to eat may be important for the treatment or prevention of obesity (Epstein, Leddy, Temple, & Faith, 2007). We have shown in a series of studies that obese adults and children are more motivated to work for palatable, favorite foods than leaner peers (Saelens & Epstein, 1996; Temple,

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Legerski, Giacomelli, Salvy, & Epstein, 2008), and those high in food reinforcement consume more food in an ad libitum eating session than those who do not find food as reinforcing (Epstein et al., 2004).

Behavioral choice theory and laboratory choice paradigms can provide a framework to understand the reinforcing value or efficacy of a food. Reinforcing efficacy or reinforcing value is a theoretical construct that can be used to understand the behavioral maintaining properties of a reinforcer (Bickel, Marsch, & Carroll, 2000; Griffiths, Brady, & Bradford, 1979). Recent research has suggested that reinforcing efficacy is not a static or homogenous construct, but rather a multidimensional or heterogeneous construct, comprised of related but distinct aspects of reinforcement that can be understood within the framework of behavioral economic demand curve analysis (Bickel et al., 2000).

Reinforcing value has traditionally been measured by determining how much effort one will engage in to gain access to food, with the magnitude of the reinforcing value proportional to the amount of work in which the individual engages. This can be established using progressive ratio schedules of reinforcement in which the participant is working only for access to food (Richardson & Roberts, 1996) or in a concurrent schedules choice situation, in which participants are working for food or another alternative, or in some situations, two different types of food (Epstein & Saelens, 2000; Epstein, Leddy et al., 2007).

Previous studies in our laboratory have assessed the reinforcing value of food using a laboratory computer based behavioral choice paradigm. One advantage of using a laboratory task is that it provides an objective measure of how hard an individual is willing to work to gain access to a reinforcer. However, this method is time consuming and limits the number of reinforcers that can be tested. In addition, and perhaps most important for the development of a theoretical basis for understanding food reinforcement, is that one session laboratory progressive ratio tasks cannot be used to establish demand curves. In this method, subjects are provided access to portions of food or alternative reinforcers if they meet the response requirements for that schedule. After obtaining a reinforcer, that schedule progressively increases until the person stops responding. Several dependent measures are available, including the schedule associated with the termination of responding, or the breakpoint, the total number of responses, and the relative distribution of responses if the study uses choice methodology. However, it is not possible to determine demand curves, since the number of reinforcers that are required before the schedule is increased is fixed. The same paradigm can be used to establish demand curves if the experiment involves multiple sessions, with each session devoted to a particular schedule. It may even be preferable to devote multiple rather than single sessions at a schedule to ensure stability of responding before moving to the next progressive ratio. This approach can be used to establish factors that alter reinforcer efficacy, but it would not be possible to use this to establish individual differences. Research on individual differences requires studying a large number of subjects, and it would be challenging to study each subject for multiple sessions to establish individual differences in how motivated they are to obtain food to eat. The development of time efficient and flexible measures of reinforcing efficacy would be of substantial utility in assessing the reinforcing value of multiple reinforcers during one study session and would substantially decrease subject burden.

There has been a questionnaire developed to measure the reinforcing efficacy of drugs (Griffiths, Rush, & Puhala, 1996) that has been adapted to study food reinforcement (Goldfield, Epstein, Davidson, & Saad, 2005). This measure has been validated, and proven to be useful in assessing individual differences in food reinforcement that interact with dopamine genetics to predict energy intake (Epstein et al., 2004). However, this measure provides a measure of breakpoint, but cannot be used to establish demand curves.

The traditional method for measuring demand is to assess the effects of changing prices on consumption. In behavioral studies price is replaced by varying response requirements, and consumption relates to the number of reinforcers obtained. Thus, purchasing tasks that vary response requirements in a progressive fashion allow for the estimation of substance consumption at a range of prices. Questionnaire versions of purchasing tasks have been developed to measure the reinforcing efficacy of nicotine in smokers (MacKillop et al., 2008) and alcohol in college drinkers (Murphy & MacKillop, 2006). Results from these studies have shown an inverse relationship between consumption and price and the cigarette purchase task has been shown to be a valid and cost effective method for assessing the reinforcing value of nicotine (MacKillop et al., 2008).

The general aim of this study was to compare the reinforcing efficacy of snack foods using a laboratory computer based measure of reinforcing efficacy (LAB) with a questionnaire that measures reinforcer efficacy (QUES). One goal of the study was to validate the QUES by examining the correspondence of the data generated by the QUES and LAB task. In addition, we also wanted to assess the relationship between the QUES and LAB tasks and several measures that may be conceptually related to food reward, including the Body Mass Index (BMI), measures of calories consumed during the ad libitum eating session as well as usual energy intake, and measures of hunger and food liking.

1. Method

1.1. Participants

Twenty four participants were studied, 12 obese (body mass index (BMI) $\geq$ 30 kg/m^2) and 12 nonobese (BMI < 30 kg/m^2) non-smoking adults between the ages of 18 and 50 (33.4 ± 11.1; mean ± SD). Seventeen percent of the participants were minorities, with an equal number of nonobese and obese male and female participants. Participants were recruited from a pool of subjects who had completed a study looking at dopamine genotypes, food reinforcement and energy intake. Participants were excluded from the original study if they were taking medications associated with loss of appetite, were smokers, had diabetes, had previously been diagnosed with an eating disorder or psychiatric disorder (e.g. anxiety, depression, attention deficit hyperactivity disorder), were allergic to the ingredients in the study foods, were currently dieting, and did not rate at least a moderate liking (≥4 on a 9 point Likert-type scale) for five out of the six study foods. Participants received a $15 gift certificate to local stores for completing the study. The study was approved by the University at Buffalo Health Sciences Institutional Review Board. Participant characteristics are shown in Table 1.

1.2. Procedures

Participants visited the laboratory for three sessions, an ad libitum snack-eating task, the food reinforcement task, and the reinforcing efficacy questionnaire. All three experimental sessions were scheduled between the hours of 2 PM and 5 PM, during a normal period that individuals would consume additional calories outside of meal time. Participants were asked to refrain from consuming food or drinking beverages, other than water, for at least 3 h prior to the test session and to refrain from consuming the experimental foods in the 24 h prior to the test session. Upon initial arrival at the laboratory, participants read and signed consent forms, completed a same day and 24 h food recall and hunger questionnaires. Participants then completed the food purchase questionnaire. Prior to the start of each session participants were provided with a preload of a Luna Sunrise Blueberry Bliss or Strawberry Crumble Breakfast bar (Clif Bar & Company; Berkeley, CA, 42 g, 150 kcal, 4 g fat, 23 g carbohydrates, 7 g protein) to minimize the effects of hunger on energy intake and food reinforcement. The inclusion of a standard preload increases the ability to show individual differences in food reinforcement

(Reiss & Havercamp, 1996). Demographic information, height and weight measurements and three dietary habits questionnaires were administered during the ad libitum eating session.

1.2.1. Ad libitum eating task—The ad libitum food consumption task was presented as a taste test. Participants were provided 200–309 kcal (42–60 g) servings of six palatable, high-energy density snack foods (amount of food presented (g) and energy density (kcal/g) shown in parentheses): Wavy Lay's Potato Chips (57 g, 5.4); Cooler Ranch Doritos (60 g, 5.0); M&M's (60 g, 5.0); Twix (48 g, 5.0); Kit Kat (42 g, 4.8); and Butterfinger (57 g, 4.5). Water was provided ad libitum. Participants were told that they could consume as much or as little of the food that they wanted as long as they tasted each food so that they could accurately rate the food's characteristics. Participants rated each food on a number of different characteristics including pleasurability, sweetness, blandness, flavorfulness and bitterness using 9-point Likert-type scales. Participants were then given eating questionnaires to complete. Food from the taste test was left in the room and participants were told that the food would be discarded after the session and they could continue eating if they choose to do so. When participants indicated that they were finished, they were asked to identify their favorite food from among the six available and told that this was the food that would be used in the food reinforcement and food purchasing test sessions. Once the questionnaires were completed, participants' height and weight measurements were taken and they were given a reminder for the food reinforcement visit. This visit was scheduled 2–3 weeks after the ad libitum eating session.

1.2.2. Food reinforcement (LAB) task—The reinforcing value of food was measured by determining the number of responses participants made for food or food alternatives on progressive ratio schedules of reinforcement. The experimental environment included two computer stations that participants could go back and forth between. At one station, participants could earn points toward food and at the other station they could earn points for time to spend reading *Time* and *Newsweek* magazines. This alternative activity was provided to reduce the likelihood that participants would engage in responding out of boredom. Participants were instructed on how to use the computer task and given a practice session. Following the instructions for the task, the experimenter left the room. An intercom and closed circuit video system were present in the room so the experimenter could observe the participant and the participant could communicate with the experimenter.

The reinforcement task is similar to a slot machine with shapes that rotate on the screen and a point is earned each time the three shapes match in shape and color. For every five points earned, the subject was able to receive a 67–103 kcal (14–20 g) portion of his or her preferred snack food selected during the ad libitum eating session or 2 min of time to spend reading depending on which reward they were working for. The programmed reinforcement schedules for food and reading were progressive fixed ratio schedules with response requirements of 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048 and so forth for each point. Participants were instructed to perform one activity at a time (i.e. play the computer game, eat or read), and that the session would end when they no longer wished to earn points for access to food or time to spend reading. Water was provided ad libitum.

The food reinforcement task generates an overall response curve showing responding for food across the levels of reinforcement. The task also generates a total number of responses made for a reinforcer across all levels of reinforcement and was used to generate a breakpoint for responding, which was defined as the first reinforcement schedule (i.e. 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048) for which responding was zero. The LAB O_{max} was defined as the maximal amount of responses made on the highest reinforcement schedule completed and the LAB P_{max} was defined as the reinforcement schedule (i.e. 4, 8…2048) at which expenditure was maximized.

1.2.3. Food purchasing questionnaire (QUES task)—The food purchasing task was modified from the cigarette purchase task (CPT) (Bickel & Madden, 1999) and assessed a number of different metrics of relative reinforcing efficacy. The procedure we used was modified to assess the relative reinforcing efficacy of snack foods. The snack food used in the task was a 67–103 kcal portion (14–20 g) of the participant's preferred snack food selected during the ad libitum eating session. The preferred food was displayed in front of the participant during the task so that they had a frame of reference when completing the questionnaire. The instructional set for the task was as follows:

> Imagine a TYPICAL DAY during which you eat snack foods. The following questions ask how many portions of snack food you would consume if they cost various amounts of money. The available snack food is _____ (preferred snack food). Assume you have the same income/savings that you have now and NO ACCESS to any snack food other than the snack food offered at these prices. In addition, assume that you would consume the snack food that you request on that day; that is you cannot save or stockpile snack food for a later date. Please respond to the questions honestly. Participants were then asked to respond to the following question: How many portions of _____ (preferred snack food) would you consume if they were ____ each at the following 19 prices?: Zero (free), $0.01, $0.05, $0.13, $0.25, $0.50, $1, $2, $3, $4, $5, $6, $11, $35, $70, $140, $280, $560, $1120. The prices were presented in ascending order.

The QUES task used in this study generates a food demand curve, reflecting the quantitative relationship between demand for food and escalating price, and generated five QUES indices: (a) breakpoint (i.e. the first price at which consumption was zero), (b) intensity of demand (i.e. consumption at the lowest price), (c) elasticity of demand (i.e. sensitivity of snack food consumption to increases in cost), (d) QUES O_{max} (i.e. maximum expenditure for snack food) and (e) QUES P_{max} (i.e. price at which expenditure was maximized). Individual demand elasticities were obtained using Mixed Effects Regression Models (MRM) which allow for regression analyses to test predictors of repeated dependent measures (Hedeker & Gibbons, 2006). In the models to estimate individual elasticity coefficients, the intercept was considered a random variable and price was considered a fixed effect. Log values of both the purchases and prices were used in the model.

1.3. Measurement

1.3.1. Dietary recalls—At the beginning of each session, participants were interviewed by the experimenter, using a multi pass same day and 24 h food recall, to verify adherence to the study protocol that they had not consumed food or drink (except water) 3 h prior to the appointment and that they had not eaten the preferred snack food in the 24 h prior to the appointment. Briefly, the first pass included making a quick, uninterrupted list of all the foods and beverages consumed. For the second pass, the experimenter reviewed the quick list and probed for any large gaps of time between eating bouts. For the third pass, the experimenter returned to the beginning of the list and asked for portion sizes as well as any condiments, added fats and added sugars that may have been added to the food item. The final pass was to prompt the participant to recall any other foods that they may have forgotten, such as foods that were eaten in small amounts. Measuring cups and spoons, rulers and pictures of portions of food were provided to help the participants estimate portion sizes. The total number of calories consumed was calculated for the recall based on manufacturers' labels and the Food Works nutrition database (Nutrition Company, 2007). Usual energy intake was calculated based on a 3-day average of the 24 h dietary recalls collected the day prior to the testing days.

1.3.2. Demographics—The Hollingshead (Hollingshead, 1975) demographics questionnaire was used to assess socioeconomic status on the basis of education level, income,

occupation and race. Highest education attained was scored as 1 = less then 7th grade, 2 = Jr. high (9th grade), 3 = some high school (10th–11th grade), 4 = high school, 5 = some college or vocational training, 6 = completed 2 year college degree, 7 = completed 4 year college degree, 8 = completed graduate degree.

1.3.3. Height and weight—The participant's weight and height were measured using a digital scale (TANITA Corporation of America Inc, Arlington Heights, IL) and a digital stadiometer (Measurement Concepts & Quick Medical, North Bend, WA). On the basis of height and weight data, body mass index (BMI) was calculated according to the following formula: BMI = kg/m^2. Individuals were considered obese if their BMI was at least 30 kg/m^2 and nonobese if their BMI was less than 30 kg/m^2 (NHLBI Obesity Education Initiative Expert Panel, 1998).

1.3.4. Eating questionnaires—Participants completed the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985), the Questionnaire of Eating and Weight Patterns (QEWP) (Spitzer et al., 1992), and the Binge Eating Scale (BES) (Gormally, Black, Daston, & Rardin, 1982). The TFEQ is a validated instrument to detect dietary restraint (Allison, Kalinsky, & Gorman, 1992) with three subscales that assess dietary restraint, hunger and disinhibition. The QEWP and BES are used to assess binge eating disorder. Participants were identified as potentially having binge eating disorder if they scored higher than 27 on the BES or were indicated as having the disorder by the QEWP. Any participant identified as potentially having binge eating disorder was required to complete the Eating Disorders Examination (Bryant-Waugh, Cooper, Taylor, & Lask, 1996), administered by a trained personnel in an additional session. No participants in this subsample met the criteria for binge eating disorder.

1.3.5. Food liking, hunger—Subjective ratings of hunger were collected pre and post intake of the preload and after all three test sessions using a 10-point Likert-type scale. Food hedonics was also measured pre and post intake of the preload and after the session for the food reinforcement session as well as during the food purchasing questionnaire. For hunger, 1 indicated not at all hungry/not at all full and 10 indicated extremely hungry/extremely full, while for hedonics 1 indicated not liking at all and 10 indicated liking very much.

1.4. Analytic plan

Pearson product–moment correlations were used to compare performance on the food reinforcement LAB task to the food purchasing QUES questionnaire, as well as the relationships between BMI, laboratory and usual energy intake and hunger and liking. All analyses were conducted using SYSTAT 11.0 (Systat Software, 2004).

2. Results

Participant characteristics are shown in Table 1. As shown in Fig. 1, food consumption exhibited a decelerating trend in response to price increases and response output conformed to an inverted U-shaped function. The amount of money spent on purchases increased up to a cost of $1.20, and the amount then gradually decreased until no purchases were made when the price exceeded $5.00 per portion (Fig. 2). Fig. 3 shows the increase in responding over trials as the behavioral requirements to obtain food increased. All subjects were willing to make enough responses to complete the FR16 schedule to obtain food, as shown by the absence of deviation. Individual differences began at the FR32 schedule, and differences continued up to the FR1024 schedule. No subject responded at the FR2048 schedule. Table 2 shows the characteristics of responding on the questionnaire QUES task. The average own-price or demand elasticity was −0.27. The negative relationship shows that as price increases, purchases

decrease. The elasticity coefficient suggests a reduction in purchasing of the snack foods of 2.7% for a 10% increase in price.

As shown in Table 3, all QUES measures were significantly correlated with one another, with the highest correlations being between QUES P_{max} and QUES Breakpoint which approached a correlation of 1.0, consistent with previous studies (Bickel & Madden, 1999;Johnson & Bickel, 2006). In addition, there were high correlations between measures on the LAB task. The univariate correlations between the QUES O_{max} and LAB O_{max} and LAB P_{max} were both 0.45 ($p = 0.03$) and the univariate correlation between the QUES O_{max} and the LAB number of total responses over all reinforcement schedules was 0.44 ($p = 0.03$). In addition, QUES elasticity of demand was significantly correlated with LAB breakpoint ($r = -0.45$, $p < 0.05$) and with the LAB O_{max}, P_{max} and total responses ($r = -0.47$, $p < 0.05$).

Table 4 shows correlations of the QUES and LAB indices with variables conceptually related to eating and obesity. BMI was correlated with both the LAB O_{max} ($r = 0.52$, $p = 0.009$) and the QUES O_{max} ($r = 0.43$, $p = 0.04$). There was also a significant correlation between the LAB total number of responses made on the food reinforcement task and BMI ($r = 0.51$, $p = 0.01$), as well as the demand elasticity for the QUES task and all the LAB measures except for the breakpoint. Laboratory energy intake correlated with all the LAB measures, and elasticity for the QUES measures. Usual energy intake was also correlated with all the LAB measures, but none of the QUES measures. Food liking was also related to all the LAB measures, but none of the QUES measures. Dietary restraint was related to the demand elasticity for the QUES task ($r = 0.47$, $p = 0.02$), but none of the LAB measures; however, dietary hunger was related to all of the LAB measures, but none of the QUES measures. Educational level was not related to any of the QUES or LAB measures.

3. Discussion

In the current study, we compared performance on a questionnaire approach to measuring reinforcer efficacy with performance on a traditional progressive ratio behavioral choice relative reinforcing value paradigm. Results showed that performance on the questionnaire QUES task was significantly positively associated with performance on the LAB laboratory measure. The QUES O_{max} and the elasticity of the demand curve generated from the QUES task showed positive associations with the LAB O_{max} and the LAB P_{max} and the total responses made over all schedules of reinforcement. None of the other QUES indices (e.g. P_{max}, Breakpoint, etc.) were significantly correlated with performance on the computer based measure.

We also sought to validate the QUES task used in this study as a time and cost efficient measure of the reinforcing efficacy of snack foods, generating results that converge with previous studies using purchasing tasks (MacKillop et al., 2008; Murphy & MacKillop, 2006). The results from the QUES task were topographically consistent with what is typically observed in laboratory food purchasing studies (Epstein, Dearing, Paluch, Roemmich, & Cho, 2007; Epstein et al., 2006). The measure showed some convergent validity with the O_{max} and the elasticity of the demand curve being highly correlated with BMI and the elasticity of the demand curve being highly correlated with the total calories consumed during the laboratory session. There were inconsistent relationships between dietary restraint or hunger as measured by the TFEQ (Stunkard & Messick, 1985) and the questionnaire and laboratory tasks, with elasticity on the questionnaire related to dietary restraint, and hunger related to all aspects of laboratory responding.

In addition, we also examined the relationship between different facets of reinforcement generated by the QUES task. There were significant correlations between the different

measures of RRE, with most measures being highly correlated with one another. The highest correlations were between the P_{max} observed and the breakpoint which approached collinearity, consistent with previous studies (Bickel & Madden, 1999; Johnson & Bickel, 2006).

While there were similarities in the values derived from the two measures, there may be important differences in how the measures are related to energy consumed in the laboratory or usual energy consumption or food liking. Both the QUES and LAB tasks showed relationships with energy intake in the laboratory, but only the LAB task was strongly related to usual energy intake or food liking. One advantage to using paper and pencil based measures of food reinforcement is that it is time and cost efficient and allows researchers to test the reinforcing efficacy of multiple reinforcers in one test session. Traditionally, reinforcing efficacy can be measured with either absolute or relative reinforcing value depending on whether only one or multiple options are available. The pattern of responding in single versus concurrent schedules of reinforcement may be the same, such that a food that is very reinforcing in one paradigm is also very reinforcing in the other paradigm (Bickel et al., 2000). The QUES task used in this study only provided participants with one reinforcer option, and responding may have been different if there had been an alternative reinforcer to snack foods present such as another food or a sedentary activity. The QUES task also presented hypothetical purchasing decisions, as subjects did not actually purchase and consume foods. Perhaps most important, the QUES task can be used to generate demand elasticity curves, which may be a preferred way to assess reinforcing efficacy (Bickel et al., 2000; Johnson & Bickel, 2006). Laboratory behavioral choice measures to assess reinforcing efficacy assess the pattern of responding to progressive ratio schedules, but require assessment of responding at each schedule in separate sessions, which makes determination of individual differences in the reinforcing efficacy of food challenging.

Another method that has been used to establish the reinforcing value or efficacy of food is the use of experimental analog purchasing tasks in which the price of one commodity is manipulated and the price of another commodity is held constant. Studies in our laboratory have looked at the utility of using behavioral analogs of food purchasing to explain purchasing behavior which thus influences consumption. We have shown in a series of studies that as the price of a particular food increases consumption of that food will decrease and vice versa (Epstein, Dearing et al., 2007; Epstein et al., 2006). These studies have been used to establish demand curves and can be used to determine the own and cross price elasticity for different commodities. Future research comparing performance on traditional progressive schedules of reinforcement with analog purchasing tasks may yield another alternative method for establishing the reinforcing value of foods. A food that is highly reinforcing may also display greater degrees of price inelasticity when measured using an analog purchasing task.

There are several limitations to the study. For example, the sample size was small, and we did request that participants not consume the experimental foods for the day prior to the test session. This may have affected their usual energy consumption on the day prior to testing and therefore relationships with usual energy intake measured during the 3 days prior to coming to the laboratory should be interpreted with caution.

The findings from the present study suggest that in some situations, questionnaire versions of reinforcing efficacy that establish demand curves, as well as providing traditional measures of responding based on progressive increases in response requirements (cost), can be used in place of or in conjunction with computer based paradigms to establish the behavioral maintaining properties of food. Perhaps the best use of the questionnaire is as a screening tool to get an idea of potential reinforcers that would be then tested using the laboratory behavioral choice paradigm. Additional research is needed to compare to other purchasing tasks that can be used

to establish demand elasticity, as well as whether demand curves are more strongly related to obesity than other measures of reinforcing efficacy. In the present study the maximal responding to progressive ratio schedules (O_{max}) was slightly more related to BMI and laboratory energy intake than the food purchasing elasticity, which warrants more research to replicate this finding, and establish whether demand curves can be used to predict who will respond to behavioral obesity interventions, whether the task can be used with children, with different types of food, and whether individual differences in elasticity of demand predicts the development of obesity in prospective studies.

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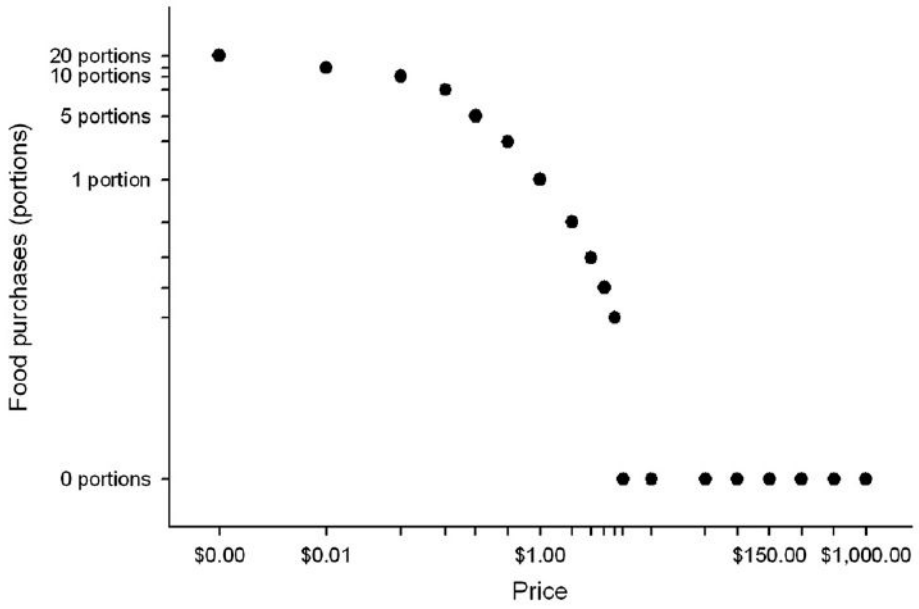

Fig. 1.

Food demand in the questionnaire food purchasing task. Conventional log–log coordinates are used for portionality, with zero values replaced with trivial nonzero values for the purposes of plotting on a logarithmic scale.

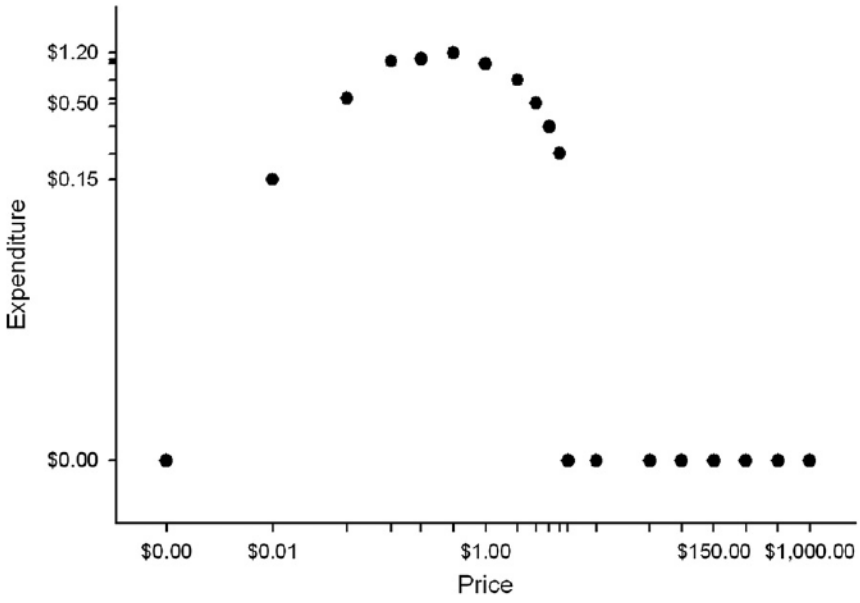

Fig. 2.

Expenditure for snack foods in the questionnaire food purchasing task. Conventional log–log coordinates are used for portionality, with zero values replaced with trivial nonzero values for the purposes of plotting on a logarithmic scale.

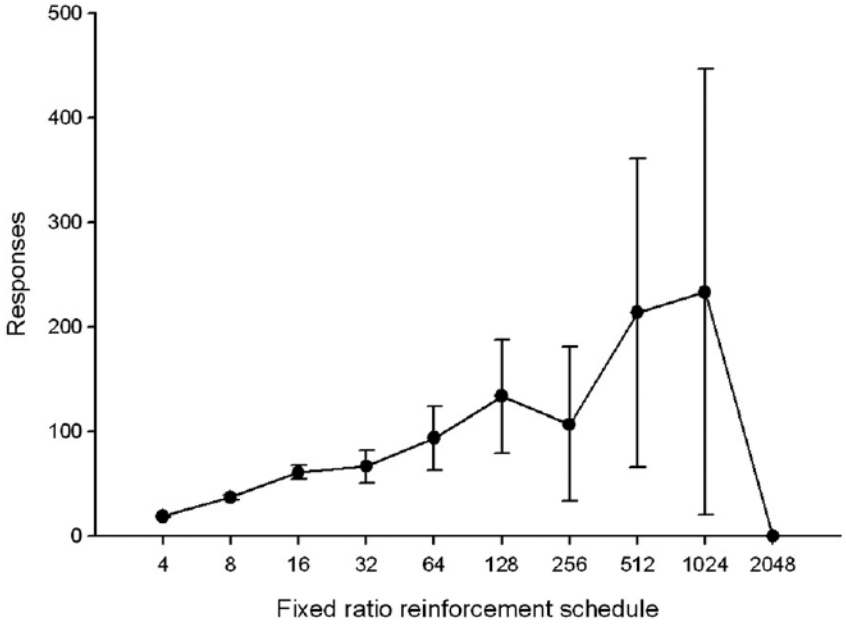

Fig. 3.
Responding for snack foods (mean ± SEM) across fixed ratio schedules of reinforcement.

Table 1

Participant characteristics.

Variable	(*M* ± SD)
N (male/female)	24 (12/12)
Age (years) (*M* ± SD)	33.4 ± 11.1
BMI (kg/m^2)	30.9 ± 9.8
Dietary restraint	6.3 ± 3.7
Dietary disinhibition	6.8 ± 3.2
Dietary hunger	5.2 ± 3.4
Binge Eating Scale	10.9 ± 7.7
Baseline hunger QUES	6.1 ± 1.8
Food liking RRE	7.4 ± 1.8
Baseline hunger LAB	6.1 ± 1.3
Food liking LAB	7.6 ± 1.7
Laboratory energy intake	685.2 ± 284.3
Usual energy intake	2172.4 ± 731.4
Race: *n* (%)	
Caucasian	20 (83%)
African American	2 (8 %)
Asian	2 (8 %)
Education: *n* (%)	
High school	12 (50)
College	12 (50)

Table 2

Means and standard errors for the relative reinforcing efficacy (RRE) and relative reinforcing value of food (LAB) tasks.

Variable	*M*	SE	Range
QUES breakpoint	$1.99	0.31	$0.25–$6.00
QUES intensity (portions)	17.54	8.18	2.00–200.00
QUES O_{max}	$1.94	0.29	$0.26–$5.20
QUES P_{max}	$1.02	0.27	$0.13–$5.00
QUES elasticity	−0.27	0.02	−0.54 to −0.14
LAB breakpoint (FR schedule)	237.00	114.96	0.00–2048.00
LAB O_{max} (responses)	482.17	228.3	0.00–5120.00
LAB P_{max} (FR schedule)	96.33	45.67	0.00–1024.00
LAB total responses	966.33	464.53	0.00–10,220.00

Note: QUES breakpoint: price at which consumption was zero; QUES intensity: intensity of demand (i.e. consumption at lowest price); QUES O_{max}: maximum expenditure for snack food; QUES P_{max}: price at which expenditure is maximized; QUES Elasticity: individual elasticities based on analyses using Mixed Effects Regression Models in which the intercept was considered a random variable and price was considered a fixed effect. Log values of the purchases and prices were used in the model; LAB breakpoint: the first reinforcement schedule (i.e. 4, 8…2048) for which responding was zero; LAB O_{max}: the maximal amount of responses made on the highest reinforcement schedule completed; LAB P_{max}: the reinforcement schedule (i.e. 4, 8 …2048) at which expenditure was maximized; LAB total responses: the total number of responses made for a reinforcer across all levels of reinforcement.

Table 3

Correlations among relative reinforcing efficacy (RRE) and relative reinforcing value of food (LAB) tasks.

Variable	Q-BP	Q-I	Q-O	Q-P	Q-E	L-BP	L-O	L-P	L-T
QUES breakpoint (Q-BP)	1.00								
QUES intensity (Q-I)	0.56**	1.00							
QUES O_{max} (Q-O)	0.82***	0.58**	1.00						
QUES P_{max} (Q-P)	0.91***	0.59**	0.66**	1.00					
QUES elasticity (Q-E)	−0.65***	−0.76***	−0.83***	−0.48*	1.00				
LAB breakpoint (L-BP)	0.01	0.12	0.35	−0.19	−0.45*	1.00			
LAB O_{max} (L-O)	0.02	0.15	0.45*	−0.17	−0.47*	0.94***	1.00		
LAB P_{max} (L-P)	0.02	0.15	0.45*	−0.17	−0.47*	0.94***	1.00***	1.00	
LAB total responses (L-T)	0.02	0.14	0.44*	−0.18	−0.47*	0.95***	1.00***	1.00***	1.00

QUES breakpoint (Q-BP): price at which consumption was zero; QUES intensity (Q-I): intensity of demand (i.e. consumption at lowest price); QUES O_{max} (Q-O): maximum expenditure for snack food; QUES P_{max} (Q-P): price at which expenditure is maximized; QUES elasticity (Q-E): individual elasticities based on analyses using mixed effects regression models in which the intercept was considered a random variable and price was considered a fixed effect. Log values of the purchases and prices were used in the model; LAB Breakpoint (L-BP): the first reinforcement schedule (i.e. 4, 8…2048) for which responding was zero; LAB O_{max} (L-O): the maximal amount of responses made on the highest reinforcement schedule completed; LAB P_{max} (L-P): the reinforcement schedule (i.e. 4, 8 …2048) at which expenditure was maximized; LAB total responses (L-T): the total number of responses made for a reinforcer across all levels of reinforcement.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Table 4

Correlations among relative reinforcing efficacy (RRE), relative reinforcing value of food (LAB) and BMI and measures or eating.

Metric	BMI	Lab kcal	BL hunger	Recall kcal	BL liking	TFEQ restraint	TFEQ hunger	TFEQ disinhibition	EDU
QUES task									
Breakpoint	0.07	−0.03	0.21	−0.14	−0.01	−0.30	0.23	0.04	0.06
Intensity	0.26	0.28	0.40*	0.21	0.26	−0.24	−0.01	−0.02	−0.16
O_{max}	0.43*	0.28	0.30	0.24	0.21	−0.36	0.47*	0.23	0.01
P_{max}	−0.07	−0.21	0.09	−0.29	−0.09	−0.18	0.07	−0.15	0.01
Elasticity	−0.48*	−0.52**	−0.39	−0.34	−0.27	0.47*	−0.35	−0.18	0.10
Lab task									
Breakpoint	0.38	0.62**	0.21	0.67**	0.44*	−0.09	0.50*	0.26	0.22
O_{max}	0.52**	0.60**	0.28	0.75**	0.41*	−0.05	0.52**	0.36	0.17
P_{max}	0.52**	0.60**	0.28	0.75**	0.41*	−0.05	0.52**	0.36	0.17
Total responses	0.51**	0.61**	0.27	0.74**	0.42*	−0.06	0.52**	0.35	0.18

The lab kcals are based on food consumed during the ad-lib eating task, while recall kcal were the average daily intake based on the 3 days of food recalls. Baseline hunger and liking values are based on values that day for that task. EDU = Highest level of education completed. TFEQ: Three Factor Eating Questionnaire.

* $p < 0.05$.

** $p < 0.01$.