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Measurement of food reinforcement in preschool children: Associations with food intake, BMI, and reward sensitivity

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Abstract

Progressive ratio (PR) schedules of reinforcement have been used to measure the relative reinforcing value (RRV) of food in humans as young as 8 years old; however, developmentally appropriate measures are needed to measure RRV of food earlier in life. Study objectives were to demonstrate the validity of the RRV of food task adapted for use among preschool children (3 to 5y), and examine individual differences in performance. Thirty-three children completed the RRV of food task in which they worked to access graham crackers. They also completed a snack task where they had free access these foods, liking and hunger assessments, and their heights and weights were measured. Parents reported on their child's reward sensitivity. Overall, children were willing work for palatable snack foods. Boys and older children made more responses in the task, while children with higher BMI z-scores and reward sensitivity responded at a faster rate. Children who worked harder in terms of total responses and response rates consumed more calories in the snack session. This study demonstrates that with slight modifications, the RRV of food task is a valid and developmentally appropriate measure for assessing individual differences in food reinforcement among very young children.

Keywords

food reinforcement; progressive ratio; children; obesity; BMI; reward sensitivity; food intake; validity; gender differences; age differences

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INTRODUCTION

Food is a powerful reinforcer—it maintains the behavior on which its delivery or acquisition is dependent—and its reinforcing value is a salient determinant of food intake (Lappalainen & Epstein, 1990). Measured using operant responding protocols in which an individual works to obtain a food reward (e.g., by pressing a lever), the reinforcing value of food refers to how much an individual is willing to work for a reward (Epstein, Bulik, Perkins, Caggiula, & Rodefer, 1991; Epstein, Leddy, Temple, & Faith, 2007; Hodos, 1961) and reflects their motivation to consume this food (Depoortere, Li, Lane, & Emmett-Oglesby, 1993; Roberts, Loh, & Vickers, 1989). Higher reinforcing value of food has been linked to overweight in children and adults (Epstein, Temple, et al., 2007; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008), greater body weight in rats (Ferguson, 1997), and excessive weight gain in childhood (Hill, Saxton, Webber, Blundell, & Wardle, 2009). Studying the development of food reinforcement early in life may further our ability to measure and understand early antecedents of obesity; however, developmentally appropriate measures of food reinforcement have not been adapted and validated for use with very young children. The objectives of the current study were to demonstrate the validity of a relative reinforcing value (RRV) of food task adapted to be developmentally appropriate for preschool children, and examine individual differences in task performance.

Among the growing number of human food reinforcement studies published in the past decade, the laboratory-based RRV of food task developed by Epstein and colleagues (Epstein, Leddy, et al., 2007; Lappalainen & Epstein, 1990; Rollins, Dearing, & Epstein, 2010; Temple et al., 2008) has been one of the most frequently utilized. Grounded in the traditions of operant responding and behavioral economics research conducted with animal models, primarily the rat, the RRV of food task measures the relative reinforcing value of one food when an alternative is readily available. In this task, an individual has an opportunity to work for access to two food rewards (or a food and a non-food alternative) concurrently on independent progressive-ratio (PR) schedules of reinforcement. With PR schedules, the amount of work required to obtain a food reward increases after each reward is obtained (e.g. 4, 8, 16, etc. level presses). The RRV of food can be measured as the breakpoint—i.e., the last completed ratio—or a variety of alternatives including the total number of responses made to access the food, or how quickly those responses are made (i.e. response rate).

To our knowledge, only one study has used a PR reinforcement schedule in very young children. In Chelonis, Gravelin, and Paule (2011), children aged 4 to 14 were given the opportunity to earn nickels on a PR schedule of 1, 11, 21, 31, and so on, for up to 10 minutes. Young children were willing to work on a PR schedule to access monetary rewards, and the breakpoints were higher for older children and boys. To date, however, individual differences in young children's performance on PR schedules to access food rewards has not been demonstrated. The RRV food task has only been used in children as young as 8 years old (e.g., Temple et al., 2008), and needs validation among younger children.

Performance on PR schedules is mediated in part by mesolimbic dopaminergic pathways that have also been implicated in addictive behaviors of drug abuse (Depoortere et al., 1993; Roberts et al., 1989), gambling (Comings et al., 1996), and more recently, chronic overeating (Johnson & Kenny, 2010; Stice, Yokum, Zald, & Dagher, 2011). Consequently, there is growing interest in examining PR performance as a predictor of risk for obesity, characterized by having greater preference, responsiveness, and consumption of palatable, energy-dense foods (Davis et al., 2007). For example, being overweight has been shown to predict greater motivation to work in the RRV of food task for palatable foods among children and adults (Epstein, Dearing, & Roba, 2010; Epstein & Wright, et al., 2004; Saelens & Epstein, 1996; Temple et al., 2008). Children with greater reward sensitivity may also be predisposed to find highly palatable foods very reinforcing. Reward sensitivity is a psycho-biological trait mediated by the behavioral activation system that refers to having greater responsiveness to incentives and appetitive reinforcers (Gray, 1981; Pickering & Gray, 1999). Past studies show that individuals with high reward sensitivity are more susceptible to environments with easy access to fast food (Paquet et al., 2010) and have greater responsiveness to palatable, energy-dense foods (Beaver et al., 2006).

The objectives of the current study were to demonstrate the validity of a RRV of food task adapted to be developmentally appropriate for preschool children, and to examine individual differences in children's performance. Our first objective was to describe children's performance on the task, measured as the number of responses and response rate (i.e., number of clicks per minute) made for two very similar foods. The data for this study were gathered as part of a larger study, in which the RRV protocol was used to assess change in children's RRV of two types of food (i.e. Scooby Doo™ and Sponge Bob™ graham crackers) after access to one of the foods was restricted. The data were collected prior to the experimental manipulation, and the foods were selected to meet the needs of this larger study. While it is somewhat unusual to use two very similar foods concurrently in a RRV of food task—in past studies, typically a food item is compared to a non-food alternative (e.g., reading)—our purpose is to simply demonstrate the task for use in very young children, and investigate relations between RRV performance and individual characteristics that have been demonstrated in past work (e.g., Temple et al., 2008). In our second objective, we investigated whether individual differences in RRV performance differed by age and gender, BMI, and reward sensitivity. We hypothesized that children who had higher BMIs and reward sensitivity would demonstrate higher total responses and response rates. The third objective was to demonstrate the predictive validity of the task by investigating the relation between RRV performance and children's intake of the study foods in an ad libitum snack session. We hypothesized that children with greater total responses and response rates would consume more calories of each snack food.

METHODS

Participants

Participants were 42 children (ages 3–5) and their parents attending a university-based, full-day daycare in University Park, Pennsylvania. Exclusion criteria included having a health condition that could impact food intake and known food allergies. Children from five

classrooms were recruited via letters addressed to their parents; parents provided consent for their family's participation. Upon providing consent, parents were asked to complete a brief survey measuring household demographics and child reward sensitivity. Mothers completed the majority of all surveys (80%). For the current paper, we excluded children who did not complete the RRV of food or ad libitum eating tasks ($n = 9$), due to behavioral difficulties ($n=1$), failure to understand instructions ($n=2$), illness (e.g. cold, flu) ($n=3$), or family travel ($n=3$). This reduced the final sample to 33.

Procedures

The procedures were administered in two sessions completed in a separate room in the preschool facility 2.5 to 3 hours after children had a standard lunch. Study sessions lasted no longer than 35 minutes, replaced the standard school-served afternoon snack, and were completed on separate days (no more than 4 days apart), with multiple measures occurring during the second session. Children's heights and weights were measured at the end of the study.

In the first session, children completed the ad libitum snack task. Children were seated in small groups of 4–7 children with a trained staff member at each table in their classrooms. Two large bowls of Scooby Doo™ graham crackers (in the shape of bones) and Sponge Bob™ graham crackers (in the shape of squares) were placed in the center of the table, and children were instructed to serve themselves using 1/3-cup scoops. Children were also served an 8-ounce carton of skim milk. Snack sessions were videotaped.

In the second session, children completed the hunger, liking, and RRV of food tasks, in that order. The hunger assessment was re-administered following the RRV of food task to measure changes in hunger. If a child reported that they were full during the baseline hunger assessment, the RRV of food task was not administered. Up to 2 more attempts were made within 1–4 days to complete the RRV of food task; on the 3rd attempt, the RRV of food task was administered regardless of fullness. Twenty-three children completed the task on the first attempt; only 4 completed it on the third attempt. After the task, children were offered an 8-ounce carton of skim milk and 30-gram portion of another neutrally-liked snack food to meet school snack requirements (11 children accepted the food). Based on observations, the hunger task lasted 1–2 minutes and the liking task ~1 minute. The total session (i.e., liking, hunger, and RRV of food tasks) lasted no longer than 35 minutes, and time spent in the RRV of food task was limited to 30 minutes. Parents were compensated \$10 for their family's participation and each classroom received \$50. The Pennsylvania State University Institutional Review Board approved all study procedures.

Measures

Ad libitum snack task—Children's ad libitum intakes of the two graham crackers were measured using video-recordings of a snack session scheduled at the regular snack time. Number of pieces eaten was later coded by trained research assistants. All research assistants were trained until they independently achieved 70% on a criterion videotape. Inter-rater agreement was acceptable for both graham crackers (ICC's = .78 – .88). To obtain the number of calories consumed for each graham cracker, the average gram weight

of a piece of each graham cracker was previously determined by weighing 20 pieces of each brand and then calculating the mean weight of each brand. These average gram weights were used to convert number of pieces eaten into grams. Using manufacturer's information, number of grams eaten was converted into calories consumed. In addition, a %intake score was created representing the amount of calories consumed of Scooby Doo™ graham crackers divided by total calories consumed of both graham crackers.

Hunger Assessment—A protocol, previously developed to assess hunger and fullness in 5-year-old girls (Fisher & Birch, 2002), was utilized in the current study to measure children's level of hunger and fullness prior to and after the RRV of food task. Children were read a story about “Peter Peter Pumpkin Eater”, in which a character called Peter, who as he eats pumpkins, goes from being hungry to full as shown by pictures of Peter with (1) an empty stomach, (2) a half empty/full stomach, and (3) a full stomach. Children were asked to indicate their own level of hunger/fullness on a 3 point scale, using these three cartoon figures of Peter Peter Pumpkin Eater.

Liking Assessment—Children's liking of the study foods was measured using a liking assessment protocol created by Birch (1979). Children were interviewed individually by trained interviewers. During the interview, the child was first familiarized with three non-gendered faces visually representing “really yummy”, “really yucky”, or “just okay” to ensure that they understood the meaning of each category. The child was then asked to categorize each food, in self-selected order, by first tasting it and then placing it in front of the face that best represented their liking of that food. After all the foods were categorized, the child was focused on the “yummy” category and asked to choose the most liked food of those in this category. That food was then removed and the child was asked to choose the yummiest amongst the remaining foods. This procedure was repeated for the “just okay” foods and “really yucky” foods, to obtain ranked liking scores. This task was completed at the beginning of the study in order to select the two study foods to be used from among a group of six sweet snack foods (i.e., honey-flavored goldfish, cinnamon-flavored goldfish, cinnamon-flavored cereal, vanilla cookies, Scooby Doo™ graham crackers, and Sponge Bob™ graham crackers). Scooby Doo™ and Sponge Bob™ graham crackers were selected because they were similar in liking (ranked scores: 4.1 vs. 4.1), macronutrient composition, and energy density (calories/gram: 4.5 vs. 4.5). Immediately before the RRV of food task, children's liking of the two graham crackers was reassessed and only this liking data will be presented in the current paper. Liking scores ranged from 1 (yucky) to 3 (yummy).

RRV of food task—RRV of snack foods was measured by the RRV of food task (Epstein, Wright, et al., 2004; Rollins et al., 2010), which has been previously utilized among adults and children young as 8 years old (e.g., Temple et al., 2008) and is similar to PR protocols used in the animal drug literature (e.g., Rodefer, Campbell, Cosgrove, & Carroll, 1999; Rodefer & Carroll, 1999). Based on a pilot study we conducted with 3–4 year old children, several steps were taken to improve the task's use in the preschool setting and to make it developmentally-appropriate for young children. Data collection stations were created (see Figure 1) that were easy to set-up, dismantle, and transport, and could be used to administer the task at the preschool facility. To reduce distractions, children worked in cubicles in a

separate room and extraneous stimuli were hidden (e.g., computer screens). In addition, the task instructions were simplified to be developmentally-appropriate for preschoolers. In each station, two computer mice were placed on a small desk. Consistent with RRV of food protocols used in older samples (Epstein, Dearing, Temple, & Cavanaugh, 2008; Temple et al., 2008), the computer mice were connected to two hidden computers which recorded the number of clicks, number of schedules completed, and the length of time spent clicking each computer mouse by the child. The child had the option to work for access to one-piece portions of Scooby Doo™ graham crackers (~3.4 grams/piece) on one mouse and Sponge Bob™ graham crackers (~2.3 grams/piece) on another mouse. A picture of each food was affixed next to its respective mouse. Both mice were on independent, concurrent PR schedules. Lights located beneath each picture indicated to the child when s/he had earned a food reward. The schedule of reinforcement for both graham crackers began at 4 and then doubled (8, 16, 32, 64, 128, 256, 512, 1028, 2056) each time a reward was earned. For example, the child initially clicked the computer mouse button four times to earn a portion of one food, but after the first portion was earned, the child had to click eight times for the next portion, and then double that amount for the third portion. This same reinforcement schedule has been used among older children and adults (Rollins et al., 2010; Temple et al., 2008), and was found to be appropriate for preschool children in a pilot study, which compared this schedule to the less demanding one described in Chelonis et al. (2011). Children were instructed that they 1) would receive the rewards as soon as they were earned, 2) could only click on one mouse at a time, and 3) would be finished when they no longer wished to earn access to any of the graham crackers. Children were asked to tell the interviewer when they were finished earning snacks. Children were instructed that they could eat their rewards as they earned them and anytime during the task, but that they could not take the rewards with them. Each child was left alone in the station to complete the task, and the interviewer only returned to give earned snack foods to the child immediately after each food was earned, or to answer questions, or resolve behavioral disturbances (e.g. child started singing loudly), and to complete the session when the child was finished eating or earning snacks, or when the total session time had reached 30 minutes. Children's intake of the snack foods was measured, and caloric and gram intakes were computed using the manufacturer's information. RRV of each graham cracker was operationalized as total responses, total schedules completed, and response rate (responses/minute) made for each food.

Reward sensitivity—Children's reward sensitivity was measured using the BAS scale, originally created by Carver and White (1994) and modified for preschool children (parent-report; Blair, 2003; Blair, Peters, & Granger, 2004). The BAS is composed of 13 items that comprise 3 scales: BAS drive ("When my child wants something he/she goes all out to get it"; 4 items), BAS reward responsiveness ("It would excite my child very much to win a prize"; 5 items), and BAS fun seeking ("My child acts on the spur of the moment"; 4 items). Response options range from 1= "extremely untrue" to 7= "extremely true" and were averaged to create a larger BAS scale. Good internal consistency was observed for the current sample ($\alpha = .79$).

Anthropometrics—Children's height and weight were measured in triplicate by a trained staff member. BMI percentiles and BMI z-scores were calculated using the 2000 CDC Growth Charts (Kuczmarski et al., 2000); BMI percentiles of 85th were used to classify children as overweight and >95th as obese.

Data analysis

All data analyses were completed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Paired t-tests were used to assess mean differences between the study foods for the following variables: total responses, response rate, liking, and ad libitum intake of the study foods, and to examine change in hunger ratings measured before and after the RRV of food task.

Pearson correlations were used to examine relations between RRV performance (i.e., number of responses, response rates), eating behaviors (liking, hunger, ad libitum intake), and child characteristics (age, BMI z-scores, reward sensitivity) by study food. ANOVA was used to examine mean differences in RRV performance by age and gender. To adjust for child age, gender, BMI z-scores, and liking, the previous correlations and ANOVA models were rerun as partial correlations or ANCOVAs, respectively. In addition, to assess whether having the RRV of food task terminated (i.e. when it reached 30 minutes) influenced the partial correlations, a variable representing termination was constructed (1=session was terminated, 0=not terminated) and tested as a covariate. It did not significantly modify any of the findings and therefore will not be presented.

All data were examined for extreme outliers using boxplots, normality plots, and scatterplots (when examining relations). Outliers were tested to see if they significantly modified the results. One outlier was identified that modified the significance of the correlation between RRV responses and intake of Sponge Bob, and was therefore removed when computing this correlation.

RESULTS

Participant characteristics are shown in Table 1. On average, children were 4.5 ± 0.7 (mean $\pm$ SD) years old, from middle- to high-income households, and primarily white, non-Hispanic. Children had BMI percentiles of 50.7 ± 28.6 and 14.0% of the sample was overweight or obese, which is below national estimates for this age group (Ogden, Carroll, Kit, & Flegal, 2012). In addition, as shown in Table 1, children's liking and ad libitum intake of the Scooby DooTM crackers and Sponge BobTM crackers were not significantly different.

RRV performance

No child earned all of the snacks (i.e. 11 portions of each food) and 9 children (75% female, 4.7 ± 0.8 years old) had their RRV of food task terminated at 30 minutes due to time constraints. On average, children worked 14.2 ± 10.1 minutes to access the snack foods. For both foods, children made a similar number of responses (276 ± 357 vs. 227 ± 341), completed the same number of PR schedules (4.3 ± 2.6 vs. 4.1 ± 2.6), and had similar response rates (62.4 ± 35.7 vs. 49.2 ± 24.2), based on paired t-tests (p 's > .05). Total

responses for Scooby Doo™ crackers and for Sponge Bob™ crackers were correlated ($r = .50, p < 0.01$), as were the response rates for the two foods ($r = .65, p < 0.001$). In addition, children who made more total responses for Scooby Doo™ crackers tended to have higher response rates for this food ($r = .30, p < 0.10$), and a similar correlation was found for Sponge Bob™ crackers ($r = .45, p < 0.05$).

On average, during the task children consumed 3.7 ± 2.4 pieces ($40.4 \text{ kcal} \pm 26.1$) and 4.0 ± 2.6 pieces ($57.6 \text{ kcal} \pm 37.1$) of Sponge Bob™ and Scooby Doo™ crackers in the RRV of food task, respectively. The difference in caloric intake between the two foods may have been due to the different sizes of Sponge Bob™ crackers (2.3 grams/piece) and Scooby Doo™ crackers (3.4 grams/piece). The amount of calories consumed in the RRV task was 40–60% of the amounts they consumed during the ad libitum snack food session (shown in Table 1). Lastly, as shown in Table 1, a significant decrease in hunger ratings was observed after the food reinforcement task ($p < 0.001$), based on paired t-tests.

Individual differences in RRV performance

Age and gender differences in RRV performance were observed. As shown in Table 2, age was positively correlated with total responses for both foods. To further investigate this finding, total responses were broken down by age and study food in Table 3 and mean differences were examined using post-hoc Tukey paired comparisons. Five-year olds made twice as many responses for both foods than 3 and 4-year old children (Table 3) and boys tended to make more responses and clicked faster than girls. It is worth noting that no gender differences were observed in liking for the two study foods. The results did not change after adjusting for covariates (age, liking, and BMI z-scores).

As shown in Table 2, children with higher response rates for both foods tended to have higher BMI z-scores and higher reward sensitivity. Lastly, children who reported being hungry prior to the task made more responses for Sponge Bob graham crackers; no relation was observed for Scooby Doo™ graham crackers or between hunger and response rates. Liking for the snack foods was not associated with RRV performance.

Predictive validity

As expected, children's total responses for each food predicted their relative caloric intake of each food during the snack sessions (Table 2). As shown in Figure 2, relative responses to the two study foods in the RRV task predicted relative intake of the two foods during snack sessions. Children with higher response rates for Scooby Doo™ graham crackers also consumed more calories of this food (Table 2). The same pattern between response rate and intake was also noted for Sponge Bob graham crackers but it only became statistically significant after adjusting for children's age, gender, liking, and BMI z-scores ($r = .46, p < .05$). The previous correlations remained statistically significant after adjusting for the covariates (i.e. age, gender, liking, and BMI z-scores).

DISCUSSION

We demonstrated the validity of a RRV of food task adapted to be developmentally appropriate for preschool children. Children were willing to work for snack foods on a

progressive ratio (PR) schedule of reinforcement that has been previously utilized among adults and older children (e.g., Rollins et al., 2010; Temple et al., 2008). Individual differences in children's RRV task performance were observed and were associated with children's age, gender, BMI, and reward sensitivity. Age and gender differences were noted; children who were older made more responses and boys made more responses than girls. Children with higher BMI z-scores and higher reward sensitivity worked at a faster rate to access these foods, a pattern consistent with previous research with older samples, providing evidence for construct validity even among this very young sample. In addition, both total responses and response rates predicted children's intake of the snack foods during a separate snack session, thereby providing evidence for the predictive validity of the RRV of food task in this age group.

Number of responses made to access snack foods increased from age 3 to 5, which is consistent with Chelonis et al. (2011) who found that as age of their participants increased, breakpoints for monetary rewards increased among a sample of 4–14 year olds. By the age of 3, most children are able to point and click on a computer mouse (Calvert, 2005). Thus, the minimal amount of work required in the current RRV of food task (i.e., clicking a child-sized computer mouse) may have minimized age effects on how much or quickly children worked in the task. We did find, however, that boys tended to have a higher response rate than girls and made twice as many responses as girls. Among the few animal and human studies that have examined sex differences in food reinforcement, the findings have been mixed (Goldfield & Lumb, 2008; Van Hest, 1988). Given our small sample, additional research is needed to further examine age and gender differences

We hypothesized that higher BMI and reward sensitivity would predict greater total responses and response rates made in the RRV of food task, and as predicted, children with higher BMIs and those who had greater reward sensitivity worked at a faster rate in the RRV of food task. This is consistent with research suggesting that there may be a risk profile for obesity (Davis et al., 2007), in which individuals who find food more reinforcing have a greater preference for energy-dense foods and are more sensitive to rewarding foods may be at greater risk for obesity, and these findings suggest that these individual differences in risk are present and can be assessed among 3 to 5 y olds. However, we did not observe a relationship between total responses made in the RRV of food task and BMI and reward sensitivity. This is inconsistent with Temple et al. (2008) who found that among 8–12 year olds, overweight children made more responses in an RRV of food task to access palatable snack foods than normal weight children. It is possible that total number of responses and response rate represent two related yet dissociable aspects of food reinforcement. Behavioral scientists have long used reaction times to measure impulsivity and reactivity in laboratory inhibition tasks such as the Go/no-go task (Avila, 2001; Cyders & Coskunpinar, 2011). Perhaps RRV response rates are a similar implicit measure of reactive and appetitive tendencies, thereby explaining the relation we observed between response rates and reward sensitivity. In contrast, total number of responses or breakpoints are traditional measures of reinforcer strength and thus, may better capture how reinforcing or rewarding an individual views a reinforcer. However, given the limited evidence, more research is needed to evaluate if response rates and number of responses differentially relate to eating behaviors and individual characteristics.

It is also possible that in the current younger sample, some children may have become tired or distracted, and stopped responding before they reached their “true” breakpoint. This is in contrast to response rates, which were quickly established after the second portion was earned (i.e. the ratio requiring 8 presses). We did find, however, that response rates and total responses made in the RRV of food task had weak to modest correlations for both study foods. This is consistent with the concept of reinforcing efficacy, in which a positive convergence is expected between the measures of total responses and response rate (Griffiths, Brady, & Bradford, 1979; Penrod, Wallace, & Dyer, 2008). Thus, in the current sample of young children, response rate may present an attractive, time-efficient outcome measure of food reinforcement.

Lastly, we hypothesized that children’s RRV of the graham crackers would predict their intake of these foods during a snack session in which they had free access to these foods. We found that total responses and response rates both predicted children’s intake, after adjusting for children’s liking of these foods and other child characteristics. This is consistent with past studies in which total responses was shown to predict intake of palatable foods among older children and adults, independent of their liking for these foods (Epstein & Wright, 2004; Temple et al., 2008). The independent effect of food reinforcement may be explained by Berridge’s incentive salience theory (Berridge, 1996; Berridge & Robinson, 2003), in which RRV of food may represent a measure of ‘wanting’ or incentive salience. Based on this theory, ‘wanting’ and ‘liking’ are two related yet dissociable constructs—the former may be more related to uncontrollable and addictive behaviors (e.g., chronic overeating).

This study has several strengths and limitations. This is the first study to present an RRV of food task adapted to be developmentally appropriate for preschool children. Individual differences in RRV performance were related to differences in children’s age and gender, and showed similar patterns of relations to those reported in studies with older individuals, with RRV performance showing predicted positive relations to BMI, reward sensitivity, and hunger, and to children’s total intake of these foods in a snack session where both foods were available. In addition, to our knowledge, this is one of the few studies to use the RRV of food task to report response rates and provide evidence that response rates predicts food intake. The study also has several limitations; the current sample was very small ($n = 33$), which might have reduced the power of our analyses, and homogenous—White, highly educated, and middle- to high-income. In addition, the ad libitum snack task was completed in a group setting with multiple children and a research staff member, while the RRV of food task was completed by each child primarily in isolation. It’s possible that children’s intake during the snack session was influenced by their peers, and if true, may have introduced measurement error into the intake data. However, within preschools settings, children tend to eat in groups and this is a more naturalistic setting than having each child eat in isolation.

In conclusion, the current study demonstrates that with minor modifications to the RRV of food task protocol, the task is a developmentally appropriate measure of individual differences in food reinforcement among preschool children. Individual differences in task performance were related to age, gender, BMI, and reward sensitivity. The RRV of food

task has become a popular measure for assessing humans' motivation to eat and may play an important role in studying the ontogeny for obesity risk profiles, in which individuals show greater responsiveness, reward sensitivity, liking, and reinforcing value for palatable snack foods.

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HIGHLIGHTS

- We examined the validity of a food reinforcement task among preschool children
- Food reinforcement task is a valid measure in children as young as 3 years old
- Greater food reinforcement predicted greater intake of snack foods
- Higher BMI and reward sensitivity predicted greater food reinforcement

Figure 1.
An individual data collection station for the relative reinforcing value (RRV) of food task

Figure 2.

Association between children's number of responses made in the RRV of food task and ad libitum intake of Scooby Doo™ graham crackers (○) and Sponge Bob™ graham crackers (●). The associations were tested using Pearson correlations.

Table 1

Child and household characteristics

Variable	(Mean $\pm$ SD)	Range
<i>N</i> (boys/girls)	33 (11/22)	
Child age (y)	4.5 (0.7)	3.0 to 5.8
Child BMI percentile ^a	50.7 (28.6)	3.2 to 95.7
Reward sensitivity ^b	4.9	3.8 to 6.4
Hunger ^c (baseline)	2.2 (0.8)	1 to 3
Hunger ^c (post)	1.5 (0.8)	1 to 3
Liking ^d – Scooby Doo™	2.8 (0.5)	1 to 3
Liking ^d – Sponge Bob™	2.6 (0.5)	2 to 3
Ad libitum intake (kcal) – Scooby Doo™	94.9 (50.4)	0 to 200.8
Ad libitum intake (kcal) – Sponge Bob™	94.8 (51.9)	10.8 to 216.8
Maternal education: <i>n</i> (%)		
College	4 (12.1%)	
Post-graduate	26 (78.9%)	
Not specified	3 (9.0%)	
Household income: <i>n</i> (%)		
\$21,000 to \$40,000	4 (12.1%)	
\$41,000 to \$80,000	5 (15.2%)	
> \$80,000	21 (63.7%)	
Not specified	3 (9.0%)	
Child race: <i>n</i> (%)		
White	25 (75.9%)	
Asian	4 (12.1%)	
Black	1 (3.0%)	
Not specified	3 (9.0%)	
Hispanic: <i>n</i> (%)		
	4 (12.1%)	

BMI = body-mass-index (kg/m²); Scooby Doo™ = Scooby Doo™ graham crackers; Sponge Bob™ = Sponge Bob™ graham crackers.

^aBMI percentiles were calculated with CDC growth charts.

^bMeasured using the preschool-version of the Behavioral Activation Scale (BAS; Blair, 2003).

^cHunger level measured prior to and after the relative reinforcing value of food task (1= stomach is empty, 3= stomach is full) using the 'Peter Pumpkin Eater' protocol (Fisher & Birch, 2002).

^dChildren's liking was measured using the Birch preference assessment (Birch, 1979), for which children indicated their liking (3="yummy", 2="just okay", 1="yucky") of the two study foods.

Table 2

Inter-correlations between RRV performance^a, eating measures, and child characteristics across study foods ($n = 33$)

	Age	BMI z-scores ^b	Reward sensitivity ^c	Liking ^d	Hunger (baseline) ^e	Ad libitum intake (kcal)
<i>Scooby Doo™ graham crackers</i>						
Total responses	.36*	-.01	.16	.06	.16	.61***
Response rate	.23	.41*	.36†	.13	-.02	.44*
<i>Sponge Bob™ graham crackers</i>						
Total responses	.40*	-.16	.21	.07	.35*	.40*
Response rate	.20	.42*	.48*	.17	.21	.30

RRV = relative reinforcing value; BMI = body-mass-index (kg/m^2).

^aTotal responses and response rates (responses per minute) made in the RRV of food task to access Scooby Doo™ and Sponge Bob™ graham crackers.

^bBMI z-scores were calculated with CDC growth charts.

^cMeasured using the preschool-version of the Behavioral Activation Scale (BAS; Blair, 2003).

^dChildren's liking was measured using the Birch preference assessment (Birch, 1979), for which children indicated their liking (3="yummy", 2="just okay", 1="yucky") of the two study foods.

^eHunger level measured prior to and after the relative reinforcing value of food task (1= stomach is empty, 3= stomach is full) using the 'Peter Pumpkin Eater' protocol (Fisher & Birch, 2002).

† $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 3

Mean (standard deviation) differences in children’s performance on the RRV of food task by age, gender, and study food among preschool children ($n = 33$)

	Age			Gender	
	3 ($n = 11$)	4 ($n = 13$)	5 ($n = 9$)	Boys ($n = 11$)	Girls ($n = 22$)
<i>Scooby Doo™ graham crackers^a</i>					
Total responses	177 (245)	216 (280)	484 (499)	449 (462) ^a	189 (263) ^b
Response rate	56.1 (29.1)	56.6 (36.8)	78.5 (41.7)	87.4 (35.3) ^a	49.3 (28.8) ^b
<i>Sponge Bob™ graham crackers^a</i>					
Total responses	70 (85) ^a	203 (201) ^{ab}	452 (552) ^b	271 (459)	204 (275)
Response rate	48.8 (20.2)	35.9 (18.8)	61.5 (27.4)	59.5 (25.1)	44.4 (23.0)

Note: RRV = relative reinforcing value. Different subscripts indicate significant group differences ($p < .05$) based on adjusted Tukey paired comparisons.

^aTotal responses and response rates (responses per minute) made in the RRV of food task to access either Scooby Doo™ and Sponge Bob™ graham crackers.