



Reinforcing value and hypothetical behavioral economic demand for food and their relation to BMI

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ABSTRACT

Food is a primary reinforcer, and food reinforcement is related to obesity. The reinforcing value of food can be measured by establishing how hard someone will work to get food on progressive-ratio schedules. An alternative way to measure food reinforcement is a hypothetical purchase task which creates behavioral economic demand curves. This paper studies whether reinforcing value and hypothetical behavioral demand approaches are assessing the same or unique aspects of food reinforcement for low (LED) and high (HED) energy density foods using a combination of analytic approaches in females of varying BMI. Results showed absolute reinforcing value for LED and HED foods and relative reinforcing value were related to demand intensity (r 's = 0.20–0.30, p 's < 0.01), and demand elasticity (r 's = 0.17–0.22, p 's < 0.05). Correlations between demographic, BMI and restraint, disinhibition and hunger variables with the two measures of food reinforcement were different. Finally, the two measures provided unique contributions to predicting BMI. Potential reasons for differences between the reinforcing value and hypothetical purchase tasks were actual responding versus hypothetical purchasing, choice of reinforcers versus purchasing of individual foods in the demand task, and the differential role of effort in the two tasks. Examples of how a better understanding of food reinforcement may be useful to prevent or treat obesity are discussed, including engaging in alternative non-food reinforcers as substitutes for food, such as crafts or socializing in a non-food environment, and reducing the value of immediate food reinforcers by episodic future thinking.

The reinforcing value of a food is measured by having people respond for food, with the response requirements for earning food specified by a schedule of reinforcement. The schedules, or the amount of work required to earn food, increase progressively. The schedule may start requiring people to make 10 responses to earn a portion of food, and then double after each time they met the schedule requirements. Initially, people will work for a reinforcer they want. However, as the amount of work increases they will reach a point in which they do not feel the reinforcer is worth the effort, and they will stop responding. Reinforcing value is assessed by determining the last work requirement or schedule a participant completes (Epstein, Leddy, Temple, & Faith, 2007). Absolute reinforcing value is measured for an individual food. Relative reinforcing value is measured using a concurrent schedules of reinforcement paradigm in which the person has a choice to respond for two concurrently available reinforcers, which can include two types of food or food versus an alternative commodity (Epstein, Leddy, et al.,

2007).

The reinforcing value of food has been cross-sectionally and prospectively related to obesity in infants (Kong, Feda, Eiden, & Epstein, 2015), children (Hill, Saxton, Webber, Blundell, & Wardle, 2009; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008), adolescents (Epstein, Yokum, Feda, & Stice, 2014) and adults (Carr, Lin, Fletcher, & Epstein, 2014; Epstein, Carr, Lin, Fletcher, & Roemmich, 2012; Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996). Reinforcing value is related to energy intake using laboratory, questionnaire, and food recall methods (Epstein, Carr, Lin, & Fletcher, 2011). The relationship between food reinforcement and obesity is mediated by energy intake (Epstein et al., 2012). Also, the relationship between low income or low education and BMI is mediated in part by food reinforcement (Lin, Carr, Fletcher, & Epstein, 2013).

A second way to measure food reinforcement is based on behavioral economic demand curves (Bickel, Marsch, & Carroll, 2000; Hursh,

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Raslear, Shurtleff, Bauman, & Simmons, 1989; Hursh & Silberberg, 2008) in which the relationship between price and purchasing is established (Johnson & Bickel, 2006). Participants indicate how much of a commodity they would purchase at progressively increasing prices (Hursh, Galuska, Winger, & Woods, 2005; Jacobs & Bickel, 1999; Johnson & Bickel, 2006). As the price increases, people indicate they would purchase less of the food until a point is reached in which an individual will no longer purchase that food. Hypothetical purchasing tasks provide demand curves that are similar to actual purchasing tasks (Amlung, Acker, Stojek, Murphy, & MacKillop, 2012; Wilson, Franck, Koffarnus, & Bickel, 2016).

Demand curves provide a number of indices of food reinforcement, including intensity, or how much people would consume if it was free (or minimally priced); breakpoint, the price at which purchases are zero; elasticity, the quantitative relationship between price and purchasing; $O_{\max}$, the maximum amount people will expend on the commodity, and $P_{\max}$, the maximal price before demand become highly price sensitive (Bickel et al., 2000; MacKillop et al., 2009).

To our knowledge, one study compared reinforcing value and hypothetical demand tasks in 24 adults balanced for sex (12 M, 12 F) and obesity (12 non-obese, 12 obese) status, with an average BMI of 30.9 (Epstein, Dearing, & Roba, 2010). Reinforcing value and behavioral demand $O_{\max}$ were related, and both were related to BMI. Reinforcing value $O_{\max}$ and demand elasticity were related to laboratory energy intake, but only reinforcing value $O_{\max}$ was related to usual energy intake, food liking or hunger. Demand elasticity was related to dietary restraint. These results show some aspects of the two measurement approaches were related and both were related to BMI. Differences were observed in relationship to laboratory or usual energy intake and restraint and hunger. The fact that the two measures of food reinforcement are related, and both types of measures were related to BMI suggest that laboratory and hypothetical approaches to measuring demand assess a similar construct, though they each may assess different aspects of food reinforcement.

The purpose of this study was to extend this research using a larger data set to investigate the relationships between the two measurement approaches across both low (LED) and high (HED) energy dense foods, whether reinforcing value and behavioral demand measures make independent contributions to the prediction of BMI, and how reinforcing value and hypothetical behavioral demand measures are related to BMI and to dietary restraint, disinhibition and hunger. Based on our previous work, we hypothesized that the two measurement approaches would be correlated, and both would independently predict BMI. However, we predict that the pattern of correlations with demographic, restraint, disinhibition and hunger would be different for the two approaches.

1. Method

1.1. Participants

The study used data from a study designed to examine the effects of taxes and subsidies on food purchasing in 217 participants (9 male/208 female). (Epstein, Dearing, Roba, & Finkelstein, 2010). The small sample of males was dropped from analysis, as the sample was too small to generalize results to men and women, or to make any gender comparisons. Data for four participants were not included based on medical problems that could interfere with task completion or food reinforcement measures (Crohn's disease, head trauma, gastric bypass), and data from 13 subjects were removed who violated trend criteria for inconsistent responding criteria in the hypothetical demand task (Stein, Koffarnus, Snider, Quisenberry, & Bickel, 2015). From the 191 participants who had valid reinforcing value and behavioral demand measures, four did not have BMI, two did not report minority status, one did not report their education level, and 23 did not report income.

1.2. Measures and derived predictor variables

1.2.1. Demographics

Information about age, race/ethnicity, income, and educational level were obtained using a standardized questionnaire (Adler, Epel, Castellazzo, & Ickovics, 2000).

1.2.2. Anthropomorphic measurement

Standardized protocols were used to assess both height and weight. Since posture, distance between feet spread apart, and orientation of the head can influence height measures, we requested people take off their shoes, stand against a wall, using markings on the floor to orient their feet, and look straight ahead. To ensure an accurate height, it was measured three times with a digital stadiometer (Measurement Concepts & Quick Medical, North Bend, WA). The median height was used for data analysis. Weight was without shoes, assessed using a Tanita digital scale (Arlington Heights, IL) removing coats or sweaters and with pockets empty. Measurements were used to calculate BMI (kg/m^2).

1.2.3. Behavioral demand purchasing task

Participants completed food purchase tasks for their preferred LED and HED snack foods chosen from a list of foods. LED foods have an energy density (ED) $\text{ED} \leq 2.0$ and included apples, bananas, mandarin oranges, low-fat strawberry yogurt, celery with dip, carrots with dip, applesauce, red seedless grapes, or pineapple chunks. HED foods have an $\text{ED} \geq 4.0$ and included nacho cheese Doritos®, milk chocolate M&M's®, Chips Ahoy! cookies, Reese's® peanut butter cups, Hershey's® chocolate, mini Oreos®, Original Pringles® Chips, or Little Debbie® zebra cakes. The energy density cutoff is based on extensive work on the influence of ED on intake (Rolls, 2005; Rolls, Drewnowski, & Ledikwe, 2005).

Participants were instructed to make hypothetical purchases of 30 g serving of their chosen food for a typical day with the restrictions of the same income, no access to any other snack food, and food could not be saved. Prices were varied over 19 increasing price points: \$0(free), \$0.01, \$0.05, \$0.13, \$0.25, \$0.50, \$1, \$2, \$3, \$4, \$5, \$6, \$11, \$35, \$70, \$140, \$280, \$560, and \$1120. Both LED and HED foods were assessed since research has shown that the reinforcing value of food can differ based on macronutrient composition (Epstein et al., 2011; Lappalainen & Epstein, 1990). The purchasing task has good test-retest reliability (Murphy, MacKillop, Skidmore, & Pederson, 2009) and has been shown to be related to energy intake of food (Epstein, Dearing, & Roba, 2010).

1.2.4. Behavioral demand dependent measures

Participants choices in the purchasing task resulted in the following facets of behavioral demand, (1) intensity (Q_0): purchases made when the food was free or of very minimal price (\$0.01), (2) $O_{\max}$: maximum expenditure (maximum purchases * price) (3) $P_{\max}$: price point where maximum expenditure was observed, (4) breakpoint: first price where 0 purchases are made, (5) demand elasticity (α): quantitative non-linear relationship (decaying slope) between raw purchasing data and price with the following equation (Koffarnus, Franck, Stein, & Bickel, 2015; Yu, Liu, Collins, Vincent, & Epstein, 2014) modified from the exponential demand equation introduced by Hursh and Silberberg (Hursh & Silberberg, 2008) to allow analysis of zero values in consumption:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 P} - 1)}$$

Here, Q is consumption, P is price, k is a constant of span of minimum to maximum consumption across all participant data in log10 units, and Q_0 and α served as dependent measures of demand intensity and elasticity, respectively. Measures were natural log-transformed and standardized prior to analysis to normalize skewed distributions. Relative values of each of the demand parameters was calculated to compare with relative reinforcing value in the choice paradigm. As an

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