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Binary components of food reinforcement: Amplitude and persistence

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ABSTRACT

Background: Demand curves provide an index of how reinforcing a food is. Research examining the latent structure of alcohol and tobacco reinforcement identified two underlying components of reinforcement, amplitude and persistence. No research has assessed latent structure of food reinforcement and how these factors are related to BMI.

Subjects and methods: Participants were 297 adults from two studies that completed food purchasing tasks to assess the following measures of relative reinforcing efficacy (RRE) of food: intensity (Q_0): purchases made when the food was free or of very minimal price, O_{max}: maximum expenditure (purchases*price), P_{max}: price point where maximum expenditure was observed, breakpoint: first price where 0 purchases are made, and demand elasticity (α): quantitative non-linear relationship between purchasing and price. Principal components analysis was used to examine the factor structure of RRE for food across samples and types of food.

Results: Both studies revealed two factor solutions, with P_{max}, $O_{max,}$ breakpoint and α loading on factor 1 (persistence) and intensity (Q_0) loading on factor 2 (amplitude) across both high and low energy dense foods. Persistence reflects an aggregate measure of price sensitivity and amplitude reflects the preferred volume of consumption (how long vs. how much). The two factors accounted for between 91.7 and 95.4% of the variance in food reinforcement. Intensity for high energy dense foods predicted BMI for both studies ($r = 0.18$ and $r = 0.22$, p's < 0.05).

Conclusions: The latent factor structure was similar across two significantly different independent samples and across low and high energy dense snack foods. In addition, the amplitude of the demand curve, but not persistence, was related to BMI. These results suggest specific aspects of food reinforcement that can be targeted to alter food intake.

1. Introduction

Behavioral economic demand curves provide a quantitative approach to measuring the reinforcing efficacy of a commodity (Hursh, Galuska, Winger, & Woods, 2005; Johnson & Bickel, 2006). A demand curve assesses the relationship between consumption of a commodity and price. As price increases, the demand for a commodity decreases, and the shape of the decelerating function is related to the reinforcing value of the commodity. This applies to food, as if the price of a food increases, someone who finds it very reinforcing will continue to purchase the food, while someone who finds it less reinforcing will look for a substitute that costs the same or less than the originally preferred item. At some point, while people may still want the good, but they do not demand any of it at that price, and they stop purchasing it. Demand curves provide a number of indices of reinforcing efficacy, including intensity, or how much people would consume if it was free (or minimally priced), breakpoint, the price at which purchases are zero, and elasticity, the quantitative relationship between price and purchasing (Bickel, Marsch, & Carroll, 2000; MacKillop et al., 2009). Two additional indices are O_{max}, the maximum amount people will expend on the commodity, and P_{max}, the maximal price before demand become elastic (highly price sensitive).

Demand curves have been extensively used to study reinforcing

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efficacy of alcohol, cigarettes and other drugs (Aston, Metrik, & MacKillop, 2015; Bickel & Madden, 1999; Bruner & Johnson, 2014; MacKillop et al., 2009, 2010; Petry & Bickel, 1998; Shahan, Bickel, Madden, & Badger, 1999). but have been used less often to study food (Epstein, Dearing, & Roba, 2010a). The various indices of reinforcing efficacy have been studied independently, but MacKillop and colleagues showed that the indices may be grouped into factors that better represent reinforcing efficacy than the five independent measures (MacKillop et al., 2016). Understanding the latent structure of demand is valuable as it provides insight into the nature of the construct at a theoretical level and permits data reduction to reduce type I error rate inflation at a practical level. In their sample of college student drinkers, two factors emerged, with factor 1, labeled as persistence, including α (elasticity) (factor loading, 0.95), breakpoint (0.88) and P_{max} (0.90), with factor two labeled as amplitude, with intensity (Q_0) as the strongest loading variable (0.99). O_{max} was more weakly related to both persistence (0.48) and amplitude (0.65). The two factors accounted for 85% of the total observed variance, and these measures were significantly related to a number of indices of alcohol consumption, with factor 1 showing weak relationships with consumption, while factor 2 was a strong predictor of alcohol consumption, with correlations between factor 2 and drinks per week or drinks per drinking day of 0.69. Subsequently, Bidwell et al. (Bidwell, MacKillop, Murphy, Tidey, & Colby, 2012) replicated this factor structure for cigarette demand in a sample of adolescent smokers, also finding evidence of amplitude and persistence factors. In this study α (elasticity) (0.62), breakpoint (0.90), P_{max} (0.92), and O_{max} (0.73) loaded on the persistence factor and only intensity (Q_0) (0.97) loaded on the amplitude factor. Both persistence and amplitude predicted number of cigarettes smoked daily (0.17, 0.24), carbon monoxide (0.31, 0.34) and cotinine (0.20, 0.21) levels. O'Connor and colleagues (O'Connor et al., 2016) also replicated a two factor solution in adult smokers. Consistent with Bidwell (Bidwell et al., 2012) breakpoint (0.90), α (elasticity) (0.81, P_{max} (0.92) and O_{max} (0.83) loaded on persistence, and intensity (Q_0) (0.98) loaded on amplitude. Persistence was related to quit intentions and restrictions on smoking at home, while amplitude was related to quit attempts, quit intentions and restrictions on smoking at home.

Behavioral demand curves have been used infrequently to assess relative reinforcing efficacy of food (Epstein et al., 2010a). The goal of this study is to assess whether the same factors are observed for food as for alcohol and cigarette demand, and how these factors relate to BMI. Studying food reinforcement differs from alcohol or tobacco reinforcement given the diversity of food types, ranging from healthy, nutrient dense, low energy dense foods to less nutrient dense, less healthy, high energy dense foods. Since people generally find higher energy dense foods more palatable than lower energy dense foods (Drewnowski, 1998), features of the demand curve may be different for low energy dense than high energy dense foods. The reinforcing value of the food would also be expected to be related to BMI, as has been observed in both children (Epstein et al., 2015; Hill, Saxton, Webber, Blundell, & Wardle, 2009; Kong, Feda, Eiden, & Epstein, 2015; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008a) and adults (Carr, Lin, Fletcher, & Epstein, 2014; Epstein, Carr, Lin, Fletcher, & Roemmich, 2012; Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996). However, reinforcing efficacy of food may not be as strong a predictor as reinforcing efficacy for alcohol or cigarette consumption. Obesity is a disorder of energy balance, which includes energy expenditure as well as energy intake. A complete picture of obesity development or maintenance is best acquired using both sides of the energy balance equation. Food is also necessary for life, while alcohol or nicotine is not.

Previous results (Bidwell et al., 2012; MacKillop et al., 2009; O'Connor et al., 2016) suggest that intensity is the major contributor to the amplitude factor. The amplitude factor was the strongest predictor of alcohol consumption (MacKillop et al., 2009), but amplitude and persistence were equal predictors of tobacco consumption (Bidwell et al., 2012), and both predicted quit intentions and quit attempts (O'Connor et al., 2016). In sum, across several studies, research shows that both amplitude and persistence can predict different aspects of consumption of different commodities. Persistence relates to different components of the demand curve that model how consumption is related to changes in price. It could be predicted that obese people are less price sensitive than leaner people. Amplitude refers to how much a person would consume if the price was free, this setting the y-axis of the demand curve. It could also be predicted that obese people would show stronger intensity for food than leaner peers.

The utility of factor scores to predict consumption is based on the notion that the factor scores are superior to individual components of reinforcing efficacy. Thus, we will be comparing prediction of BMI for individual as well as factor scores.

2. Method

2.1. Participants

Data were used from two separate studies that had participants complete purchasing tasks to measure indices of demand and reinforcing efficacy and BMI was measured. The Grocery Store study consisted of 217 participants participating in an online grocery store to examine the effects of taxes and subsidies on purchasing (Epstein, Dearing, Roba, & Finkelstein, 2010b). Reinforcing efficacy of food data was collected as part of a battery of screening measures. The Multisite Intervention Neuroimaging Delay Discounting (MINDD) study consisted of 111 participants recruited for a study on medical adherence and delay discounting in pre-diabetic adults in a multi-site study at two study sites Buffalo, NY and Roanoke, VA.

2.2. Measures

2.2.1. Demographics

Information about age, race/ethnicity, income, and educational level were obtained using a standardized questionnaire adapted from MacArthur's network for studies on socio-economic status and health (Adler, Epel, Castellazzo, & Ickovics, 2000).

2.2.2. Anthropomorphic measurement

For the Grocery store study, height 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 assessed using a Tanita digital scale (Arlington Heights, IL). For the MINDD study height was measured in centimeters to the nearest millimeter using a SECA stadiometer (Seca Corp., Chino, CA) and weight was measured using a Tanita digital scale. Measurements were used to calculate BMI (kg/m^2).

2.2.3. Purchasing task

In the grocery store study, participants completed two food purchase tasks, one task for a low energy dense snack food (LED), and one for a high energy dense snack food (HED). Participants first chose the most preferred food from a list of foods (LED): apples, bananas, mandarin oranges, low-fat strawberry yogurt, celery with dip, carrots with dip, applesauce, red seedless grapes, or pineapple chunks; (HED): 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®