HHS Public Access

Author manuscript

Health Psychol. Author manuscript; available in PMC 2022 April 01.

Published in final edited form as:

Health Psychol. 2021 April ; 40(4): 242–251. doi:10.1037/hea0001042.

Delay Discounting and Obesity in Food Insecure and Food Secure Women

Luis R. Rodriguez[1], **Erin B. Rasmussen**[1,*], **Dante Kyne-Rucker**[1], **Maria Wong**[1], **Katie S. Martin**[2]

[1]Idaho State University

[2]FoodShare

Abstract

Objectives: The relation between food insecurity (FI) and delay discounting (DD) and probability discounting (PD) for food and money was tested in women. In addition, discounting was tested as a variable that mediates the relation between obesity and FI.

Methods: Women recruited from a community sample (*N*=92) completed questionnaires. They completed the Food Choice Questionnaire, the Monetary Choice Questionnaire, measures for food and money probability discounting (which quantify sensitivity to risk aversion), as well as demographic measures.

Results: Women with FI had higher rates of obesity and higher food DD compared to food-secure women. However, DD for money or probability discounting for food or money did not significantly differ between FI and food secure groups when controlling for significant covariates. Neither DD or PD significantly mediated the relation between FI and obesity.

Conclusions: These results suggest that FI is associated with greater impulsive food choice, but its association with other monetary discounting and probability discounting for food and money appears contingent upon other demographic factors.

Keywords

delay discounting; food; Food Choice Questionnaire; food insecurity; Monetary Choice Questionnaire; money; obesity; probability discounting

In the United States, a complex and paradoxical relation exists between poverty and obesity. Lower socioeconomic status is linked to obesity in women and in individuals who identify as non-Hispanic Black and Latino ethnicities (Ogden et al., 2017). One aspect of low socioeconomic status that appears to be a consistent poverty-related link to obesity in American populations is food insecurity (FI), which refers to economic or physical barriers that prevent consistent access to nutritious food that meets dietary needs (e.g., Martin & Ferris, 2007; Olson, 1999; Pan, et al., 2012; Townsend et al., 2001).

*Corresponding author: Dept. of Psychology, Idaho State University, Pocatello, ID 83209-8112, rasmerin@isu.edu.

One reason why those with low food security may be more likely to be obese has to do with environmental stressors and nutrition trends that interact with the reinforcing value of food underlying self-regulation process. Larger body mass among those of lower socioeconomic status is associated with increases in food reinforcement value, which can be affected by changes to food availability (Carr et al., 2011; Lin et al., 2013). Socioeconomically disadvantage is associated with lower access to necessary goods and commodities; however, individuals with low food security seem to be particularly vulnerable to changes in resource availability. Restriction of food tends to promote food-seeking responses, especially to those with low food security (Crandall & Temple, 2018; Dhurandhar, 2016).

The types and cost of foods that are available during times of lowered food accessibility is important to consider. Individuals with marginal or low food security are more likely to maximize their calories per dollar by purchasing foods that are less expensive but calorically high; often these foods are processed and higher in fat and sugar content (e.g., Champagne et al., 2007; Darmon & Drewnowski, 2004, 2008; Drewnowski & Specter, 2004). Experimental studies show that chronic consumption of high-fat and high-sugar diets leads to a “blunting” of dopamine-related reward processes that are associated with increases in body mass (Boomhower, et al, 2013; Johnson & Kenny, 2010; Pritchett & Hajnal, 2011; Robertson & Rasmussen, 2017; Wang et al., 2001). Therefore, individuals with food security may be especially at risk for obesity due to diet-related neural alterations that affect self-control.

Changes in self-control can be assessed via delay discounting (DD). Delay discounting, a facet of impulsivity, is the devaluing of an outcome with delay to its receipt (Ainslie, 1975; Caswell et al., 2015). To measure DD in humans, participants make a series of choices between a relatively small monetary reward (e.g., $10) available immediately vs. a larger delayed monetary reward (e.g., $100 in 1 day) (Rachlin, 1995; Rachlin, Raineri, & Cross, 1991). Preferences for the smaller, sooner reward over the larger, delayed reward indicate impulsivity; the converse indicates self-control. Discounting values are often determined by plotting indifference points (i.e., value at which the smaller sooner and larger, delayed outcome are equally preferred) against delay. The resulting pattern can be quantified using a hyperbolic decay function (Mazur, 1987), in which the free parameter, k, describes the rate of decay. Impulsive behavior, or higher k values, means that the value of the delayed outcome plunges more steeply at shorter delays; lower k values indicates a flatter slope and insensitivity to delay or greater self-control.

While a large literature quantifies the role of delay-based outcomes in the area of substance abuse (e.g., Bickel & Marsch, 2001; Madden, Bickel, & Jacobs, 1999; Petry, 2001), its relevance to obesity and other eating patterns , and especially the use of food-related outcomes, is relatively novel. Several studies have reported that individuals with obesity show steeper discounting for food-related (Hendrickson & Rasmussen, 2013; Hendrickson, Lawyer & Rasmussen, 2015; Rasmussen, Lawyer, & Reilly, 2010;) and monetary outcomes (e.g.,Fields, Sabet, Peal, & Reynolds, 2011; Jarmolowicz, et al., 2015; Weller et al., 2008; see also Amlung et al., 2015) than individuals with healthy-weight status based on a BMI below 25. Moreover, a longitudinal study showed that 4-year-old children who demonstrated steeper discounting were more likely 30 years later to become obese (Schlam et al., 2013).

This trend in the literature, then, suggests that discounting future rewards is likely a behavioral process involved in obesity.

Few, if any, published studies have explored DD as a mechanism of obesity in individuals who vary in their levels of food security. Because FI is correlated with obesity (Martin & Ferris, 2007; Pan et al., 2012; Townsend et al., 2001) and poorer diet quality (Robaina & Martin, 2013), which can alter reward processes that increase caloric intake and obesity risk (e.g., Johnson & Kenny, 2010; Pritchett & Hajnal, 2011; Wang et al., 2001), preference for immediate outcomes may be increased.

In addition, because of the uncertainty of food, individuals with FI may be more likely to select food that is certain (available right now), no matter what the nutritional content or long-term consequences may be, because there may not be food later. This situation may also be exacerbated by the arrival of a paycheck or a large infusion of food benefits at the beginning of a month rather than spaced throughout the month (or perhaps when food runs out). Studies using probability discounting (PD), in which choices between smaller, more certain, and larger, less certain outcomes are arranged, show that individuals with obesity are more risk averse (less risky) when it comes to food-related outcomes compared to individuals with healthy-weight (Hendrickson & Rasmussen, 2013; Rasmussen et al., 2010). This is not surprising, given that probability (sensitivity to uncertain events) and DD (sensitivity to delayed events), though separate processes, have been shown to be related to one another (e.g., Green & Myerson, 2010; Richards, Zhang, Mitchell, & de Wit, 1999). While no literature to date is published on the relation between risk-related food decisions and FI, recent literature shows that risky sexual decision-making is associated with FI (Tsai et al., 2011; Tsai & Weiser, 2014). Therefore, shifts in impulsive and risky choice may be found in populations with FI. Understanding the extent to which impulsive and risky choice differs across food security statuses may reveal etiological pathways toward obesity among this population. Further, prior research examining obesity treatments has found that impulsivity can moderate treatment outcomes, which suggests that decision-making processes are potentially relevant treatment targets (Manasse et al., 2017).

The current study, then, is the first part of a two-part study that examines the extent to which DD and PD differ between women who are food secure vs. FI. Further, the study also examined the extent to which discounting would function as a mechanism between FI and obesity status. Specifically, the researchers hypothesized women with FI would show significantly higher DD and PD for food and money and higher rates of obesity compared to food secure women. In addition, the researchers were interested in determining the extent to which DD and PD for food and money functioned as possible mechanisms between FI and obesity status. The researchers hypothesized that DD and PD for food and money would significantly mediate the relation between FI and obesity.

Methods and Materials

Participants

Sample size was determined by an a priori power analysis with an effect size of 0.15 using G*Power®; a sample of 92 resulted in an alpha=0.05 and power=0.95. Ninety-four

participants were recruited from local food pantries, fliers placed throughout the community, and social media ads in southeast Idaho. Interested participants completed a brief pre-screening interview in person or over the phone to determine eligibility. A participant was eligible if she identified as a woman, was 18 or older, and was proficient in English. In addition, participants self-reporting diagnoses of eating disorders, hemophilia, pregnancy, and HIV status within the last year were excluded from the study. Participants meeting the eligibility criteria were scheduled for a 1-1.5-hour session. Participants were asked to abstain from eating or drinking two hours prior to their participation time.

Materials and Survey Instruments

Food Choice Questionnaire (FCQ).—The FCQ (α=0.92; Hendrickson, Rasmussen, & Lawyer, 2015) is a 27-item measure of DD for hypothetical food outcomes across small (8-13 bites), medium (25-35 bites), and large (40-50 bites) magnitudes. A 5/8 inch white cube is placed in front of the participant and she is asked to imagine it is a bite of her favorite food. Within each magnitude, individuals are instructed to make choices between two hypothetical food outcomes in which one of the food outcomes is available immediately (e.g., 4 bites now) and the other is available after a delay (e.g., 8 bites in 1 hour). The range of delays for the choices is 1/2 to 24 hours. Impulsivity values are calculated for each of the three magnitudes. See Hendrickson et al (2015) for scoring of DD values.

Money Choice Questionnaire (MCQ).—The MCQ (α=0.92; Kirby & Marakovic, 1996; Kirby, Petry, & Bickel, 1999) is a 27-item of DD for hypothetical monetary outcomes across small ($25-$35), medium ($50-$60), and large ($75-$85) magnitudes. Like the FCQ, individuals are presented with choices between a smaller, immediately available amount of money (e.g., $54 now) and a larger, delay amount of money (e.g., $77 in 117 days), though the money values and delay range differ (1-360 days). See Kirby and Marakovic (1996) for scoring of DD values.

Probability Choice Questionnaires for Money and Food.—The Probabilistic Money Choice Questionnaire (PMCQ) (α=0.94; Madden et al., 2009) is a 30-item measure of PD (risk aversion) for hypothetical monetary outcomes that estimates discounting rates across small ($20 vs. $80), medium ($40 vs. $100), and large ($40 vs. $60) magnitudes. An individual makes choices between smaller, certain amounts of money (e.g., $40 for sure) versus larger, less certain amounts of money (e.g., A 6-in-11 chance [55%] of receiving $60). See Madden et al. (2009) for scoring. The Probabilistic Food Choice Questionnaire (PFCQ; α=0.93; Rodriguez, Hendrickson, & Rasmussen, 2018) is a 39-item measure of PD for hypothetical food outcomes that was adapted from the FCQ and PMCQ. The measure estimates food discounting across small (8-14 bites), medium (26-36 bites), and large (40-50 bites) magnitudes. For each magnitude, individuals select between smaller, certain amounts of food (e.g., 15 bites for sure) vs. larger, less certain amounts (e.g., 75% chance of receiving 30 bites). See Rodriguez et al (2018) for scoring.

U.S. Household Food Security Survey Module (HFSSM).—The U.S. Household Food Security Survey Module (HFSSM; Bickel, Nord, Price, Hamilton, & Cook, 2000; USDA, 2012) is an 18-item survey used to assess the food security of a household with

or without children within the past 12 months. For the purpose of the present study, the researchers altered the timeline of the measure to the past 3 months to capture the individual's most recent and/or current experience with food security concerns. The HFSSM consists of questions designed to assess an individual's circumstances regarding consistent access to a food supply that meets basic nutritional needs and concerns about the household food budget's ability to maintain an adequate supply. Each affirmative response to items is summed across the measure to obtain a single score of a household's food security status. Higher values indicate households with less food security (i.e., more FI). Scores below 3 indicate a food secure household and scores 3 and above indicate FI with higher scores indicating greater severity.

Substance Use.—Given the extensive literature examining alcohol, substance use, and discounting, the Alcohol Use Disorders Identification Test (AUDIT-C; α=0.71; Bush et al, 1998) and the Drug Abuse Screening Test (DAST-10; α=0.74; Skinner, 1982) were administered. Higher scores, on both self-report measures, indicate an increased likelihood for problematic or consequential behaviors. A score of 3 or more on the AUDIT-C is an indication of potential alcohol abuse, regardless of sex. For the DAST-10 a score of 0 indicates no problem, 1-2 a low level, 3-5 a moderate level, 6-8 a substantial level, and 9-10 a severe level of addiction. Further, individuals who endorsed smoking or use of a nicotine vaporize were administered the Fagerstrom Test for Nicotine Dependence (FTND; α=0.99; Heatherton et al, 1991) and an adaptive version of the FTND with questions focused on vaping habits, respectively.

Subjective Hunger Questionnaire (SHQ).—The SHQ is a self-report measure of time since last food consumption and subjective hunger consistent of 3 independent items. Participants report time since their last full meal and snack and rate their current hunger level on a scale of 0 to 100. The SHQ is used to control for potential food intake before the session. Previous research shows a positive association between food DD and subjective hunger (Hendrickson & Rasmussen, 2017; Rodriguez, Hendrickson, & Rasmussen, 2018).

Intellectual Functioning.—The Slosson Intelligence Test-Revised for Children and Adults (SIT-R3; Slosson, 2002) is a brief measure of intellectual functioning that estimates overall general verbal cognitive ability with a mean standard score of 100 (SD=15; average scores 85-115). Research has suggested a negative association between DD and intellectual functioning (Shamosh & Gray, 2007).

Demographic Information.—Participants provided demographic information, such as age, ethnicity, income, date since last paycheck, and marital status.

Biometric Information.—Researchers collected participants' heights using a two-meter portable ruler. Weight and percent body fat (PBF), and body mass index (BMI) were gathered and calculated using the Tanita C-300® scale and Tanita Health Ware™ software. PBF was calculated via the scale through bioelectric impedance. BMI was calculated by dividing weight in kgs by height in meters squared (kg/m^2) and was classified in the following categories: underweight (<18.5), normal weight (18.5-24.9), overweight (25.0-29.9), and obese (≥30.0; Centers for Disease Control and Prevention, 2020). Blood

glucose samples were collected using an Accu-Chek® Compact Plus glucometer. If a participant's BMI fell below 25 kg/m^2, blood glucose levels were expected to fall at or below 110mg/d; if BMI was ≥ 25 kg/m^2, blood glucose levels were expected to be at or below 140mg/dL. These blood glucose values were based upon prior discounting studies who based their cut-off criteria on guidelines set by the American College of Endocrinology (Hendrickson et al., 2015).

Block Food Frequency Screener (BFFS).—The BFFS (Block, Gillespie, Rosenbaum, & Jenson, 2000) was developed using data from the National Health and Nutrition Examination Survey and is a 27-item self-report measured used to assess an individual's intake of dietary fats, in addition to fruit and vegetable consumption. Participants report their monthly to daily consumption of specific foods within the last 30 days. Responses to items are summed to create two scores associated with qualitative descriptors of dietary fat and fruit and vegetable consumption. For dietary fats, scores are classified as follows: very low in fat (0-7), moderate fat (8-14), high fat (15-22), and very high fat (23+). Vegetable and fruit consumption scores are classified as follows: less than 3 servings per day (0-10) less than 4 servings per day (11-12), less than 5 servings per day (13-15), and 5 or more servings per day (16+).

Perceived Stress Survey (PSS).—The PSS (α=0.90; Cohen, Kamarck, & Mermelstein, 1983) is a 10-item scale that assesses an individual's appraisal of their life events as stressful. Respondents answer questions regarding their feelings of stress and ability to cope with different life stressors over the past month. Participant responses are summed; higher scores indicate higher amounts of stress than normal.

Procedure

All materials and procedures were approved by the Idaho State University Institutional Review Board. Participants that met inclusion criteria completed the study in an office-size room at a local university or in an office-size outdoor tent set up by the researchers outside of a local food pantry. After informed consent, the research assistant conducted an additional brief interview to confirm eligibility status and obtain basic demographic information (e.g., date of birth, race, and ethnicity). The participant then completed the SHQ and blood glucose measures. If the participant reported eating food or drinking any liquid less than two hours prior to her participation or was above specified cutoffs for blood glucose, she was rescheduled. Following the blood glucose sample, the research assistant administered the SIT-R3, then the HFSSM. Next, the participant completed the four discounting measures in a randomized order on a laptop. Then, she completed the DAST-10, AUDIT-C, FTND, adapted FTND for vaping, and additional demographic information was obtained (e.g., marital status, income, etc.). Finally, biometric information was obtained. Each participant who completed the study received $15 cash for compensation.

Data Analysis

The data were analyzed using IBM SPSS Statistics version 26. Two participants discontinued participation and were dropped from analyses bringing the final sample size to 92.

Consistent Responding.—Studies using choice questionnaires report patterns of responding that are consistent; that is, those that show only one switch between the smaller outcome to the larger delayed or uncertain outcome (inconsistent would mean more than one switch; see Kirby & Malokovic). This sample demonstrated relatively consistent responding across the three magnitudes of the choice questionnaires ranging from 77%-87% on the FCQ, 97%-99% on the PFCQ, 97%-98% on the MCQ, and 96%-100% on the PMCQ, which was consistent with previous studies (Hendrickson et al., 2015; Rodriguez et al., 2018). All 92 participants were included in the analyses.

Transformations.—Due to skewness of the distributions (a common finding in the discounting literature), several variables were transformed to achieve normality. Discounting values for each magnitude of the FCQ were transformed using square root transformation due to moderate skewness; log 10 transformations were used for the PFCQ, MCQ, and PMCQ magnitudes due to substantial skewness. Similarly, BMI, blood glucose, time since last meal, time since last snack, DAST-10 total scores, and AUDIT-C total scores also demonstrated significant skew and were log 10 transformed. All variables showed improved normality following their respective transformations. In addition, due to an unequal number of participants within each income category, the income variable was dichotomized with individuals who reported <$20,000 in one group (coded as 0) and individuals who reported $20,000 or greater in annual income in another group (coded as 1). This value was determined by using the poverty line guideline for a 3-person household in the state of Idaho ($21,330; U.S. Department of Health & Human Services, 2019). Similarly, the measures for cigarette and nicotine vaporizing use were dichotomized between individuals who reported use or non-use within the past year.

Covariates.—Research indicates that alcohol, nicotine, and illicit substance use, in addition to intellectual functioning, and obesity status can influence monetary discounting (e.g., Madden et al., 1999; Petry, 2001; Shamosh & Gray, 2007; Weller et al., 2008). Further, discounting research examining food outcomes has indicated that differing levels of obesity and subjective hunger can influence individuals' responding (Hendrickson & Rasmussen, 2013; 2017; Rasmussen et al., 2010). Pearson's *r* correlations were conducted to examine the extent to which the three different magnitudes of the FCQ, MCQ, PFCQ, and PMCQ were significantly associated with DAST-10, AUDIT-C, cigarette use, nicotine vape use, SIT-R3, time since last meal, time since last snack, subjective hunger, BMI, and PBF. Variables were included in the discounting analyses if they showed significant correlations across all three magnitudes.

Main analyses.—T-tests and chi-square analyses were conducted to determine if groups differed on demographic variables. Two-way repeated measures ANOVAs or ANCOVAS were run to examine main effects of food security (between-subjects) and discounting reward magnitude (within-subjects) and their interaction on discounting. Greenhouse-Geisser corrected tests were used when tests of sphericity were significant.

Mediation analyses using Hayes' PROCESS v3.4 macro (model 4; Hayes, 2018) were conducted to determine the extent to which the relation between food security status and obesity were mediated by delay and PD for food and money (Figure 1). For each discounting

task, six simple and two parallel mediator models were conducted that allowed for each magnitude to be examined separately and simultaneously with percent body fat or body mass index as the criterion variable. Food security status was dummy coded as 0=Food secure and 1=Food insecure.

Results

Participant Characteristics

Demographics of the current study sample are displayed in Table 1. Out of 92 women, 35 (38%) women were FI, whereas the remaining 57 women were food secure. Approximately 40% of participants in the FI group and 8% of the food-secure group completed data collection at local food pantries. Participant location did not statistically affect the results.

A number of food-security differences were found. Women who were food secure demonstrated higher estimated intellectual functioning scores compared to women with FI ($t(90)=2.83$, $p=0{,}006$, $d=0.6$). More women with FI reported annual incomes less than $20,000 ($\chi^2(1)=7.65$, $p=0.006$) compared to women with food security. Women with FI endorsed marriage at lower rates those with food security $\chi^2(1)=4.15$, $p<0.04$). They also are fewer servings of fruits and vegetables and had higher rates of stress.

When comparing health-related variables, women with FI showed higher BMI ($t(90)=-2.15$, $p=0.03$, $d=0.5$) and percent body fat ($t(90)=-2.22$, $p=0.03$, $d=0.5$) compared to women with food security. Blood glucose was significantly higher in women with FI compared to women with food security ($t(42.44)=-2.26$, $p=0.04$, $d=0.5$). In addition, blood glucose was negatively associated with time since last snack ($r=-0.21$, $p=0.04$) and subjective hunger ($r=-0.28$, $p=0.006$), but was not associated with time since last meal. Women with FI reported consuming fewer fruits and vegetables (t(90)=−2.22, p=0.03, d=0.5) and higher stress (t(90)=−3.06, p=0.003, d=0.7) than women with food security.

Covariates.—Pearson's r correlations revealed that expected covariates were differentially associated with different magnitudes of discounting. In addition, given that blood glucose and other demographic variables (e.g., marital status, fruit and vegetable consumption, perceived stress, etc.) significantly differed between FI and food secure participants, it was also analyzed as a potential covariate (see Appendix A–D for tables). For money DD, the MCQ showed significant negative associations with intellectual functioning across the small ($r=-0.29$, $p=0.005$), medium ($r=-0.27$, $p=0.009$). and large magnitudes ($r=-0.38$, $p<0.001$). Blood glucose was positively association with the small ($r=0.25$, $p=0.02$), medium ($r=0.29$, $p=0.005$), and large magnitudes of the MCQ ($r=0.33$, $p=0.001$). The DAST-10 showed a significant negative association with food PD (i.e., PFCQ) with the small ($r=-0.31$, $p=0.003$), medium ($r=-0.28$, $p=0.007$), and large ($r=-0.33$, $p=0.001$). The PFCQ showed a significant association with income across all three magnitudes (small $r=-0.31$, $p=0.004$: medium $r=0.27$, $p=0.008$; large $r=0.25$, $p=0.02$).

Food Delay Discounting

Figure 2 shows mean food DD scores as a function of magnitude and FI status. A two-way repeated-measure ANOVA revealed a main effect of food security status ($F(1,90)=6.08$.,

p=0.02. partial-η^2=0.06), with FI participants displaying greater levels of discounting. A significant main effect of magnitude (F(1.16, 145.08)=11.847, p<0.001, partial-η^2=0.12) was found. There were no interactions. Posthoc pairwise comparisons revealed that small magnitude was higher than medium (p=0.001) and large magnitudes (p<0.001): medium and large magnitudes did not differ.

Mediation analyses revealed no significant indirect effect of food DD on the association between FI status and PBF. However, a consistent, significant, and positive direct effect between food security status and PBF when controlling for small (b=4.59, *S.E.*=2.01 95%CI [0.61,8.59]), medium (b=4.60, *S.E.*=2.02, 95%CI[0.58, 8.62]), and large magnitudes of the FCQ (b=4.42, *S.E.*=2.02, 95%CI[0.41,8.42]) separately or simultaneously (b=4.60, *S.E.*=2.05, 95%CI[0.53, 8.67]). Further, significant associations were observed between FI status and the small (b=0.09, *S.E.*=0.05, 95%CI[0.001,0.19]), medium (b=0.11, *S.E.*=0.05, 95%CI[0.02,0.21]), and large magnitudes (b=0.11, *S.E.*=0.05, 95%CI[0.01,0.21]) of the FCQ. When PBF was replaced by BMI, results were similar. Food DD did not significantly mediate the relation between FI status and BMI; however, a significant positive direct effects were observed when controlling for the small (b=0.05, *S.E.*=0.02, 95%CI[0.006, 0.10]), medium (b=0.05, *S.E.*=0.02, 95%CI[0.001, 0.09]), and large magnitudes (b=0.05, *S.E.*=0.02, 95%CI[0.001,0.09]) of the FCQ separately and simultaneously (b=0.05, *S.E.*=0.02, 95%CI[0.02,0.10]).

Money Delay Discounting

Figure 3 shows estimated marginal means for monetary DD across magnitude and differing levels of FI. While a two-way repeated measures analysis initially revealed a significant main effect of magnitude (F(2, 180)=24.26, p<0.001, partial-η^2=0.21), a main effect of FI status (F(1,90=458.13, p<0.001. partial-η^2=0.84) and no significant interaction, these effects disappeared when controlling for estimated intellectual functioning (F(1, 88)=6.52, p=0.01, partial-η^2=0.07) and blood glucose (F(1, 88)=2.52, p=0.02, partial-η^2=0.06), which were both significantly related to monetary discounting.

When controlling for blood glucose and intellectual functioning, money DD did not significantly mediate the relation between food security status and PBF. In addition, the direct effect between food security status and PBF was not different across small, medium, or large magnitudes when included in the model separately or simultaneously. FI was not significant associated with the MCQ across any magnitude. Further, when controlling for food security status and magnitudes of the MCQ, neither intellectual functioning nor blood glucose were significantly associated with PBF. When BMI replaced PBF the results were similar.

Food and Money Probability Discounting

A two-way repeated measures ANCOVA (magnitude and FI status) revealed that income (F(1,88)=5.81, p=0.01, partial-η^2=0.06) and DAST scores (F(1,88)=8.11, p=0.005, partial-η^2=0.08) were significantly associated with food PD. However, when controlling for the effects of income and substance use, there were no significant main effects or interactions of FI or magnitude on food PD. In addition, food PD did not function as a significant

mediator between FI status and measures of obesity across magnitudes entered separately or simultaneously when controlling for income and DAST-10 total scores.

A two-way repeated measures ANOVA revealed no significant main effects of magnitude or food security status or an interaction. Similarly, mediation analyses revealed no significant indirect effect of money PD on the association between food security status and percent body fat and food security status was not significantly associated with any magnitude of the PMCQ. However, consistent significant, positive associations between food security status and percent body were observed when controlling for the small (b=4.31, $S.E.$=1.97, 95%CI[0.41,8.22]), medium (b=4.25, $S.E.$=1.99, 95%CI[0.30,8.20]), and large magnitudes (b=4.13, $S.E.$=1.97, 95%CI[0.23,8.04]) of the PMCQ separately and when entered in the model simultaneously (b=4.33, $S.E.$=2.01, 95%CI[0.34,8.31]). When BMI replaced PBF in the model, no significant indirect effect of money PD was observed between food security status and BMI although a significant direct effects of food security status on BMI was observed when controlling for small (b=0.05, $S.E.$=0.02, 95%CI[0.003,0.09]), and large (b=0.05, $S.E.$=0.02, 95%CI[0.002,0.09) magnitudes in separate models and when all three magnitudes of the PMCQ were entered simultaneously (b=0.05, $S.E.$=0.02, 95%CI[0.001, 0.09]).

Discussion

The present study was conducted to investigate the extent to which DD and PD for food and money and obesity status differed as a function of food security status in adult women as well as determine the extent to these processes functioned as potential mechanisms for FI and obesity status. The hypotheses were 1) FI women would show significantly higher discounting and rates of obesity compared to food secure women, and 2) that discounting would function as a mediator between food security and obesity status (i.e., PBF and BMI). The first hypothesis was supported; FI predicted steeper DD across three magnitudes of food and money. FI also predicted higher obesity rates. The role of discounting in the relation between obesity and FI was not supported as a mediating variable, however.

Consistent with prior literature, women with FI showed significantly higher BMI and PBF compared to food secure women (Martin & Ferris, 2007; Townsend et al., 2001). In addition, FI was also associated with lower income, lower estimated intellectual functioning, greater likelihood of being single, fewer servings of fruits and vegetables, and higher levels of stress. This too replicates and extends what has been found in previous studies with FI populations (e.g., Motlagh, Safarpour, Maskooni, Hosseini, & Noshari, 2018; Kubzansky et al., 2009; Motbainor, Worku, & Kumie, 2017; Salinas, Shropshire, Nino, & Parra-Medina, 2016; Shahan et al., 1999; Wight, Kaushal, Waldfogel, & Garfinkel, 2014). However, food-insecurity related differences in discounting varied between type (delay vs. probability) and commodity (food vs. money).

Women with FI had higher DD rates for food across three magnitudes of food compared to food-secure women. There was also a main effect of magnitude on food in which smaller bites showed higher discounting when controlling for food security status; this magnitude effect replicates previous research (Hendrickson et al, 2015; Hendrickson & Rasmussen,

2017). There were also main effects of food security status on monetary discounting, though this effect disappeared when intellectual functioning and higher blood glucose were statistically controlled.

The differences between food secure vs. FI groups make it difficult to determine the relations more precisely between food security status, blood glucose, intellectual functioning, and monetary discounting. These results suggest that the presence of a possible underlying metabolic disorder (e.g., diabetes; Epstein et al., 2020; Lebeau et al., 2016;) and/or differences in underlying executive functioning or verbal comprehension (Shamosh & Gray, 2007) ability may play an important role in discounting patterns and account for a greater amount of variance in monetary DD than food security status. In addition, the domain-specific effect observed with food, and less so with money, DD may indicate that certain individual factors are more relevant in preferences for specific commodities over others. Further research needs to be conducted to better understand the relations among these variables.

Overall, the relation between food security status and higher impulsivity extends the literature on temporal processes related to FI and poverty. One interpretation of this literature is that being in a FI state may shorten temporal windows, such that more immediate outcomes are preferred or valued than planning for the future (i.e., survival mode). What may appear as an impulsive decision to select food or money now rather than a better reward later may be a rational choice to an individual with limited food and financial resources, particularly when choices are few.

It was hypothesized that PD for food and money would be related to food security status. These hypotheses were not supported in this sample. Some studies have suggested that FI individuals demonstrate riskier behavior than food secure individuals. For example, FI individuals are more at risk for HIV, smoking, and illicit drug use (Ivers, Cullen, Freedberg, Block, Coates, & Webb, 2009; Armour, Pitts, & Lee, 2001 Strike, Rudzinski, Patterson, & Millson, 2012). Because our results suggest that riskiness for food- or money-related outcomes does not differ as a function of food security status, it may be the case that commodity-specific riskiness (i.e., sexual and drug-related outcomes over money and food) may be relevant to FI. Future research on domain-specific PD may be warranted.

The researchers also hypothesized that delay and PD processes would mediate the association observed between FI and obesity. While food security indeed predicted obesity status, no indirect effects of delay or PD for food or money were observed. This was unexpected given the literature indicating a robust relation between discounting and obesity status (e.g., Jarmacolowicz et al., 2014; Rasmussen et al, 2010; Weller et al., 2008) and other studies indicating the mediating role of self-regulation abilities between childhood experiences and obesity (Evans et al., 2012). It may be that discounting acts as a moderator as opposed to a mediator. For example, an individual with higher rates of discounting alone may not necessarily develop obesity, but when placed into a context of FI, may engage in behaviors that lead to its ultimate development. More research is needed to understand this complex relation.

Though obesity was related to FI in this study, it was not associated with food or money DD or PD in this sample. A number of studies have shown that obesity status (BMI and PBF) predicts steeper discounting for money (e.g., Jarmolowicz et al, 2014; Weller et al, 2008; see meta-analysis by Amlung et al, 2016) and food (Rasmussen et al, 2010; Hendrickson & Rasmussen, 2013, 2017; Hendrickson et al, 2015). Therefore, the lack of obesity effect in the present study was unexpected. One difference in the present study that may account for this anomaly is the sample. A substantial proportion of the variance in discounting came from FI, which may pull from the variance of a potential obesity effect, as obesity and FI were related. This is unlikely however, as controlling for FI still did not result in an obesity effect in the data. Future research should examine other factors might affect obesity and impulsivity in FI samples.

Income, which is independent from, but related to FI, is also relevant. Indeed, in the present study, significantly more FI women reported incomes less than $20,000 per year than food secure women. Further, income showed a significant association with obesity when controlling for other factors such as FI. Although FI status and income are highly related, FI can still occur amongst higher incomes. Therefore, the present results extend this literature by more carefully parsing the variance of income and other demographic variables in terms of their relative associations with obesity.

There were some limitations to this study. The direction of causality between FI and impulsivity is not clear. While FI indeed may be a state that causes impulsivity, alternatively, trait impulsivity may be the cause of FI. Walter Mischel's work (e.g., Mischel, Soda, & Peake, 1988; Mischel, Shoda, & Rodriguez, 1989, Shoda, et al, 1990, Schlam et al., 2013) shows that the inability to delay gratification in young children predicts challenges later in life such as poorer academic performance, difficulties with social and cognitive skills, challenges with self-regulation, and a higher likelihood of health problems such as obesity. Additional research suggests that challenges with self-regulatory abilities are associated with poverty (Evans et al., 2012; Griskevicius et al., 2013; Sturge-Apple et al., 2016) and mediate the relation between socioeconomic risk factors and obesity (Evans et al., 2012). Environmental stressors coupled with difficulties with self-regulation may lead to barriers in terms of sustaining successful employment options, which places one at risk for FI.

Another notable limitation to the current study is demographic characteristics of the sample. The majority of women (78%) who were enrolled in the study were of Euro-American background. This is a concern when comparing this sample to national averages, in which 73% of females are white (US Census Bureau, 2015). However, the local diversity in which recruitment was conducted suggests that 87.2% of the area is white (US Census Bureau, 2015), so recruiting efforts may be considered satisfactory at sampling the region's diversity. It is important to note, however, that FI women who are of non-white ethnicity are especially likely to have higher rates of obesity and also FI (Ogden, et al, 2017), so effortful recruitment from diverse areas is especially important for studies on FI.

In summary, the current study suggests that food impulsivity differs between food secure and FI women. Because this effect was observed with food as opposed to money, it may be the case that FI is associated with a more domain-specific effect (see Hendrickson

& Rasmussen, 2013, 2017 for example) as opposed to a general trait-like impulsivity pattern (see, e.g., Odum, 2011). Individuals or agencies that assist food-insecure populations may want to consider this behavioral process when they are designing support for their clients. Designing programs that minimize delays in obtaining outcomes may enhance better decision-making. For example, designers of food pantries can enhance client choice by allowing clients to have immediate control over the food selected or allow clients to shop more frequently. In addition, providing food benefits through the Supplemental Nutritional Assistance Program (i.e., "food stamps") twice per month rather than once per month may help with food discounting choices. This population may also benefit from learning strategies and programs that induce longer time horizons, such as mindfulness (e.g., Hendrickson & Rasmussen, 2013; 2017).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

This research was made possible by grant number 1R15AT009348-01 (PI; Rasmussen) from the National Center for Complementary and Integrative Health (NCCIH) at the National Institutes of Health. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of NCCIH.

References

Ainslie G (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. Psychological Bulletin, 82(4), 463–496. [PubMed: 1099599]

Amlung M, & MacKillop J (2011). Delayed reward discounting and alcohol misuse. The roles of response consistency and reward magnitude. Journal of Experimental Psychopathology, 2(3), 418–431. [PubMed: 25191534]

Amlung M, Petker T, Jackson J, Balodis I, & Mackillop J (2016). Steep discounting of delayed monetary and food rewards in obesity: A meta-analysis. Psychological Medicine, 46, 2423–2434. 10.1017/S0033291716000866 [PubMed: 27299672]

Armour BS, Pitts MM, & Lee CW (2008). Cigarette smoking and food insecurity among low-income families in the United States, 2001. American Journal of Health Promotion, 22(6), 386. 10.4278/ajhp.22.6.386 [PubMed: 18677878]

Bickel G, Nord M, Price C, Hamilton W, & Cook J (2000). Measuring food security in the US Guide to Measuring Household Food Security Revised. 10.1007/978-3-319-16486-1

Bickel WK, & Marsch LA (2001). Toward a behavioral economic understanding of drug dependence: Delay discounting processes. Addiction, 96, 73–86. 10.1046/j.1360-0443.2001.961736.x [PubMed: 11177521]

Bickel WK, Yi R, Kowal BP, & Gatchalian KM (2008). Cigarette smokers discount past and future rewards symmetrically and more than controls: Is discounting a measure of impulsivity? Drug and Alcohol Dependence, 96(3), 256–262. 10.1016/j.drugalcdep.2008.03.009 [PubMed: 18468814]

Block G, Gillespie C, Rosenbaum EH, & Jenson C (2000). A rapid food screener to assess fat and fruit and vegetable intake. American Journal of Preventive Medicine, 18(4), 284–288. 10.1016/S0749-3797(00)00119-7 [PubMed: 10788730]

Bobova L, Finn PR, Rickert ME, & Lucas J (2009). Disinhibitory Psychopathology and Delay Discounting in Alcohol Dependence: Personality and Cognitive Correlates. Experimental and Clinical Psychopharmacology, 17(1), 51–61. 10.1037/a0014503 [PubMed: 19186934]

Boomhower SR, Rasmussen EB, & Doherty TS (2013). Impulsive-choice patterns for food in genetically lean and obese Zucker rats. Behavioural Brain Research, 241(1), 214–221. 10.1016/j.bbr.2012.12.013 [PubMed: 23261877]

Burkhauser RV, & Cawley J (2008). Beyond BMI: The value of more accurate measures of fatness and obesity in social science research. Journal of Health Economic, 27, 519–529. 10.1016/j.jhealeco.2007.05.005

Bush K, Kivlahan DR, McDonell MB, Fihn SD, & Bradley KA (1998). The AUDIT alcohol consumption questions (AUDIT-C): An effective brief screening test for problem drinking. Archives of Internal Medicine, 158(16), 1789–1795. 10.1001/archinte.158.16.1789 [PubMed: 9738608]

Carr KA, Daniel TO, Lin H, & Epstein LH (2011). Reinforcement pathology and obesity. Current Drug Abuse Reviews 4(3), 190–196. [PubMed: 21999693]

Caswell AJ, Bond R, Duka T, & Morgan MJ (2015). Further evidence of the heterogeneous nature of impulsivity. Personality and Individual Differences, 76, 68–74 10.1016/j.paid.2014.11.059 [PubMed: 25844002]

Center for Disease Control and Prevention (2020, 6 30). Defining adult overweight and obesity. https://www.cdc.gov/obesity/adult/defining.html

Cohen S, Kamarck T, & Mermelstein R (1983). A Global Measure of Perceived Stress. Journal of Health and Social Behavior, 24(4), 385–396. 10.2307/2136404 [PubMed: 6668417]

Crandall AK, & Temple JL (2018). Experimental scarcity increases the relative reinforcing value of food in food insecure adults. Appetite, 128, 106–115. 10.1016/j.appet.2018.05.148 [PubMed: 29852205]

Darmon N, & Drewnowski A (2008). Does social class predict diet quality? American Journal of Clinical Nutrition. 10.1093/ajcn/87.5.1107

de Wit H, Flory JD, Acheson A, McCloskey M, & Manuck SB (2007). IQ and nonplanning impulsivity are independently associated with delay discounting in middle-aged adults. Personality and Individual Differences, 42(1), 111–121 10.1016/j.paid.2006.06.026

Dorosty Motlagh AR, Safarpour P, Daneshi Maskooni M, Hosseini M, & Ranjbar Noshari F (2018). Food insecurity and primary school girl students' Intelligence Quotients: A case-control study. Journal of Research in Health Sciences, 18(2), e00411. [PubMed: 29784892]

Drewnowski A (2004). Obesity and the food environment: Dietary energy density and diet costs. American Journal of Preventive Medicine, 27, 154–162. 10.1016/j.amepre.2004.06.011 [PubMed: 15450626]

Drewnowski A, & Specter SE (2004). Poverty and obesity: The role of energy density and energy costs. American Journal of Clinical Nutrition, 79, 6–16. 10.1093/ajcn/79.1.6

Dhurandhar EJ (2016). The food-insecurity obesity paradox: A resource scarcity hypothesis. Physiology & Behavior, 162, 88–92. 10.1016/j.physbeh.2016.04.025 [PubMed: 27126969]

Epstein LH, Jankowiak N, Lin H, Paluch R, Koffarnus MN, & Bickel WK (2014). No food for thought: moderating effects of delay discounting and future time perspective on the relation between income and food insecurity. American Journal of Clinical Nutrition, 100(3), 884–890. 10.3945/ajcn.113.079772

Epstein LH, Paluch RA, Stein JS, Quattrin T, Mastandrea LD, Bree KA, Sze YY, Greenawald MH, Biondolillo MJ, & Bickel WK (2020). Delay discounting, glycemic regulation and health behaviors in adults with prediabetes. Behavioral Medicine, 1–11. 10.1080/08964289.2020.1712581

Evans GW, Fuller-Rowell TE, & Doan SN (2012). Childhood cumulative risk and obesity: The mediating role of self-regulatory ability. Pediatrics, 129(1), e68. 10.1542/peds.2010-3647 [PubMed: 22144695]

Fields SA, Sabet M, Peal A, & Reynolds B (2011). Relationship between weight status and delay discounting in a sample of adolescent cigarette smokers. Behavioural Pharmacology, 22(3), 266–268. 10.1097/FBP.0b013e328345c855 [PubMed: 21430520]

Fremstad SA (2010). Modern framework for measuring poverty and basic economic security. Washington, DC: Center for Economic and Policy Research.

Green L, Myerson J, Lichtman D, Rosen S, & Fry A (1996). Temporal discounting in choice between delayed rewards: The role of age and income. Psychology and Aging, 11(1), 79–84. 10.1037/0882-7974.11.1.79 [PubMed: 8726373]

Griskevicius V, Ackerman JM, Cantu SM, Delton AW, Robertson TE, Simpson JA, Thompson ME, & Tybur JM (2013). When the economy falters, do people spend or save? Responses to resource scarcity depend on childhood environments. Psychological Science, 24(2), 197–205. 10.1177/0956797612451471 [PubMed: 23302295]

Gundersen CG, & Garasky SB (2012). Financial management skills are associated with food insecurity in a sample of households with children in the US. Journal of Nutrition, 142, 1865–1870.

Hayes AF (2018). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach (2nd ed.). The Guildford Press.

Heatherton TF, Kozlowski LT, Frecker RC, Fagerstrom KO (1991). The Fagerstrom Test for Nicotine Dependence: a revision of the Fagerstrom Tolerance Questionnaire. British Journal of Addiction, 86, 1119–27. [PubMed: 1932883]

Hendrickson KL, & Rasmussen EB (2013). Effects of mindful eating training on delay and probability discounting for food and money in obese and healthy-weight individuals. Behaviour Research and Therapy, 51(7), 399–409. 10.1016/j.brat.2013.04.002 [PubMed: 23685325]

Hendrickson KL, & Rasmussen EB (2017). Mindful eating reduces impulsive food choice in adolescents and adults. Health Psychology, 36(3), 226–235. 10.1037/hea0000440 [PubMed: 27808529]

Hendrickson KL, Rasmussen EB, & Lawyer SR (2015). Measurement and validation of measures for impulsive food choice across obese and healthy-weight individuals. Appetite, 90(1), 254–263. 10.1016/j.appet.2015.03.015 [PubMed: 25796210]

Holt DD, Newquist MH, Smits RR, & Tiry AM (2014). Discounting of food, sex, and money. Psychonomic Bulletin and Review, 21(3), 794–802. 10.3758/s13423-013-0557-2 [PubMed: 24338570]

Ivers LC, Cullen KA, Freedberg KA, Block S, Coates J, & Webb P (2009). HIV/AIDS, undemutrition, and food insecurity. Clinical Infections Diseases, 49(7), 1096–1102. 10.1086/605573

Jarmolowicz DP, Cherry JBC, Reed DD, Bruce JM, Crespi JM, Lusk JL, & Bruce AS (2014). Robust relation between temporal discounting rates and body mass. Appetite, 78, 63–67. 10.1016/j.appet.2014.02.013 [PubMed: 24650831]

Johnson MW, & Bickel WK (2008). An Algorithm for Identifying Nonsystematic Delay-Discounting Data. Experimental and Clinical Psychopharmacology, 16(3), 264–274. 10.1037/1064-1297.16.3.264 [PubMed: 18540786]

Johnson PM, & Kenny PJ (2010). Dopamine D2 receptors in addiction-like reward dysfunction and compulsive eating in obese rats. Nature Neuroscience, 13(5), 635–641. 10.1038/nn.2519 [PubMed: 20348917]

Jones J, & Sullivan PS (2016). Age-dependent effects in the association between monetary delay discounting and risky sexual behavior. SpringerPlus, 5(1), 5–8. 10.1186/s40064-016-2570-1 [PubMed: 26759744]

Kirby KN, & Maraković NN (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. Psychonomic Bulletin and Review, 3(1), 100–104. 10.3758/BF03210748 [PubMed: 24214810]

Kirby KN, Petry NM, & Bickel WK (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. Journal of Experimental Psychology. General, 128(1), 78–87. 10.1037/0096-3445.128.1.78 [PubMed: 10100392]

Kubzansky LD, Martin LT, & Buka SL (2009). Early Manifestations of Personality and Adult Health: A Life Course Perspective. Health Psychology, 28(3), 364–372. 10.1037/a0014428 [PubMed: 19450043]

Lawyer SR, Williams SA, Prihodova T, Rollins JD, & Lester AC (2010). Probability and delay discounting of hypothetical sexual outcomes. Behavioral Processes, 84, 687–692. 10.1016/j.beproc.2010.04.002

Lebeau G, Consoli SM, Le Bouc R, Sola-Gazagnes A, Hartemann A, Simon D, Reach G, Altman J, Pessiglione M, Limosin F, & Lemogne C (2016). Delay discounting of gains and losses, glycemic control and therapeutic adherence in type 2 diabetes. Behavioural Processes, 132, 42–48. 10.1016/j.beproc.2016.09.006 [PubMed: 27663668]

Lin H, Carr KA, Fletcher KD, & Epstein LH (2013). Food reinforcement partially mediates the effect of socioeconomic status on body mass index. Obesity, 21, 1307–1312. 10.1002/oby.20158 [PubMed: 23754824]

Madden GJ, Bickel WK, & Jacobs EA (1999). Discounting of delayed rewards in opioid-dependent outpatients: Exponential or hyperbolic discounting functions? Experimental and Clinical Psychopharmacology, 7(3), 284–293. 10.1037/1064-1297.7.3.284 [PubMed: 10472517]

Madden GJ, Petry NM, & Johnson PS (2009). Pathological gamblers discount probabilistic rewards less steeply than matched controls. Experimental and Clinical Psychopharmacology, 17(5), 283–290. 10.1037/a0016806 [PubMed: 19803627]

Manasse SM, Flack D, Dochat C, Zhang F, Butryn ML, & Foreman EM (2017). Not so fast: The impact of impulsivity on weight loss varies by treatment type. Appetite, 113, 193–199. 10.1016/j.appet.2017.02.042 [PubMed: 28257940]

Martin KS, & Ferris AM (2007). Food insecurity and gender are risk factors for obesity. Journal of Nutrition Education and Behavior, 39(1), 31–36. 10.1016/j.jneb.2006.08.021 [PubMed: 17276325]

Mazur JE (1987). An adjusting procedure for studying delayed reinforcement. In Quantitative Analyses of Behavior: V. The Effect of Delay and of Intervening Events on Reinforcement Value (Vol. 5, pp. 55–73). 10.1016/j.pbb.2008.06.017

McKerchar TL, Green L, & Myerson J (2010). On the scaling interpretation of exponents in hyperboloid models of delay and probability discounting. Behavioural Processes, 84(1), 440–444. 10.1016/j.beproc.2010.01.003 [PubMed: 20074627]

Mischel W, Shoda Y, & Peake PK (1988). The nature of adolescent competencies predicted by preschool delay of gratification. Journal of Personality and Social Psychology, 54(4), 687–696. 10.1037/0022-3514.54.4.687 [PubMed: 3367285]

Mischel W, Shoda Y, & Rodriguez MI (1989). Delay of gratification in children. Science, 244(4907), 933 LP–938. 10.1126/science.2658056. [PubMed: 2658056]

Motbainor A, Worku A, & Kumie A (2017). Household food insecurity is associated with both body mass index and middle upper-arm circumference of mothers in northwest Ethiopia: A comparative study. International Journal of Women's Health, 9, 379–389.10.2147/IJWH.S130870

Odum AL (2011). Delay discounting: Trait variable? Behavioural Processes, 87(1), 1–9. 10.1016/j.beproc.2011.02.007 [PubMed: 21385637]

Ogden CL, Fakhouri TH, Carroll MD, Hales CM, Fryar CD, Li X, & Freedman DS (2017). Prevalence of obesity among adults, by household income and education—United States, 2011-2014, Morbidity and Mortality Weekly Report, 66(50), 1369–1373. 10.15585/mmwr.mm6650ai [PubMed: 29267260]

Olson CM (1999). Nutrition and health outcomes associated with food insecurity and hunger. J. Nutr, 129(2), 521S–524S. https://doi.org/0022-3166/99 [PubMed: 10064322]

Pan L, Sherry B, Njai R, & Blanck HM (2012). Food insecurity is associated with obesity among US adults in 12 states. Journal of the Academy of Nutrition and Dietetics, 119(9), 1403–1409. 10.1016/j.jand.2012.06.011

Petry NM (2001). Substance abuse, pathological gambling, and impulsiveness. Drug and Alcohol Dependence, 63, 29–38. 10.1016/S0376-8716(00)00188-5 [PubMed: 11297829]

Pritchett CE, & Hajnal A (2011). Obesogenic diets may differentially alter dopamine control of sucrose and fructose intake in rats. Physiology and Behavior, 140(1), 111–116. 10.1016/j.physbeh.2011.04.048

Rachlin H (1995). The value of temporal patterns in behavior. Current Directions in Psychological Science, 4(6), 188–192. 10.1111/1467-8721.ep10772634

Rachlin H, Raineri A, & Cross D (1991). Subjective probability and delay. Journal of the Experimental Analysis of Behavior, 55(2), 233–244. 10.1901/jeab.1991.55-233 [PubMed: 2037827]

Rasmussen EB, Lawyer SR, & Reilly W (2010). Percent body fat is related to delay and probability discounting for food in humans. Behavioural Processes, 83(1), 23–30. 10.1016/j.beproc.2009.09.001 [PubMed: 19744547]

Rasmussen EB, Robertson SH, & Rodriguez LR (2016). The utility of behavioral economics in expanding the free-feed model of obesity. Behavioural Processes, 127, 25–34. 10.1016/j.beproc.2016.02.014 [PubMed: 26923097]

Richards JB, Zhang L, Mitchell SH, & de Wit H (1999). Delay or probability discounting in a model of impulsive behavior: effect of alcohol. Journal of the Experimental Analysis of Behavior, 71(2), 121–143. 10.1901/jeab.1999.71-121 [PubMed: 10220927]

Robaina KA, & Martin KS (2013). Food insecurity, poor diet quality, and obesity among food pantry participants in Hartford, CT. Journal of Nutrition Education and Behavior, 45(2), 159–164. 10.1016/j.jneb.2012.07.001 [PubMed: 23219294]

Robertson SH, & Rasmussen EB (2017). Effects of a cafeteria diet on delay discounting in adolescent and adult rats: Alterations on dopaminergic sensitivity. Journal of Psychopharmacology, 31(11), 1419–1429. 10.1177/0269881117735750 [PubMed: 29067887]

Rodriguez LR, Hendrickson KL, & Rasmussen EB (2018). Development and quantification of measures for risky and delayed food and monetary outcome choices. Behavioural Processes, 151(1), 16–26. 10.1016/j.beproc.2018.02.020 [PubMed: 29499343]

Salinas JJ, Shropshire W, Nino A, & Parra-Medina D (2016). Food insecurity, not stress is associated with three measures of obesity in low-income, Mexican-American women in South Texas. Food and Public Health, 6(6), 149–156. 10.5923/j.fph.20160606.01 [PubMed: 29644147]

Schlam TR, Wilson NL, Shoda Y, Mischel W, & Ayduk O (2013). Preschoolers' delay of gratification predicts their body mass 30 years later. Journal of Pediatrics, 162(1), 90–93. 10.1016/j.jpeds.2012.06.049

Shamosh NA, & Gray JR (2007). Delay discounting and intelligence: A meta-analysis. Intelligence, 36(4), 289–305. 10.1016/j.intell.2007.09.004

Shoda Y, Mischel W, & Peake PK (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. Developmental Psychology, 26(6), 978–986. 10.1037/0012-1649.26.6.978

Skinner HA (1982). The drug abuse screening test. Addictive Behaviors, 7(4), 363–371. 10.1016/0306-4603(82)90005-3 [PubMed: 7183189]

Strike C, Rudzinski K, Patterson J, & Millson M (2012). Frequent food insecurity among injection drug users: Correlates and concerns. BMC Public Health, 12(1), 1058. 10.1186/1471-2458-12-1058 [PubMed: 23216869]

Sturge-Apple ML, Suor JH, Davies PT, Cicchetti D, Skibo MA, & Rogosch FA (2016). Vagal tone and children's delay of gratification: Differential sensitivity in resource-poor and resource-rich environments. Psychological Science, 27(6), 885–893. 10.1177/0956797616640269 [PubMed: 27117276]

Townsend MS, Peerson J, Love B, Achterberg C, & Murphy SP (2001). Food insecurity is positively related to overweight in women. The Journal of Nutrition, 131(6), 1738–1745. 10.1093/jn/131.6.1738 [PubMed: 11385061]

Tsai AC, Bangsberg DR, Emenyonu N, Senkungu JK, Martin JN, & Weiser SD (2011). The social context of food insecurity among persons living with HIV/AIDS in rural Uganda. Social Science and Medicine, 73(12), 1717–1724. 10.1016/j.socscimed.2011.09.026 [PubMed: 22019367]

USDA. (2014). 2012 Census of Agriculture: United States Summary and State Data. USDA National Agricultural Statistics Service, 1. 10.1109/FPGA.2003.1227249

U.S. Department of Health & Human Services (2019). 2019 Poverty Guidelines. https://aspe.hhs.gov/2019-poverty-guidelines

Van den Berk-Clark C, Myerson J, Green L, & Grucza RA (2018). Past trauma and future choices: differences in discounting in low-income, urban African Americans. Psychological Medicine, 48, 2702–2709. 10.1017/S0033291718000326 [PubMed: 29463327]

Wang XT, & Dvorak RD (2010). Sweet future: Fluctuating blood glucose levels affect future discounting. Psychological Science, 21(2), 183–188. 10.1177/0956797609358096 [PubMed: 20424042]

Wang GJ, Volkow ND, Logan J, Pappas NR, Wong CT, Zhu W, … Fowler JS (2001). Brain dopamine and obesity. Lancet, 357(9253), 354–357. 10.1016/S0140-6736(00)03643-6 [PubMed: 11210998]

Weller RE, Cook EW, Avsar KB, & Cox JE (2008). Obese women show greater delay discounting than healthy-weight women. Appetite, 51, 563–569. 10.1016/j.appet.2008.04.010 [PubMed: 18513828]

Wight V, Kaushal N, Waldfogel J, & Garfinkel I (2014). Understanding the link between poverty and food insecurity among children: Does the definition of poverty matter? Journal of Children and Poverty, 20(1), 1–20. 10.1080/10796126.2014.891973. [PubMed: 25045244]

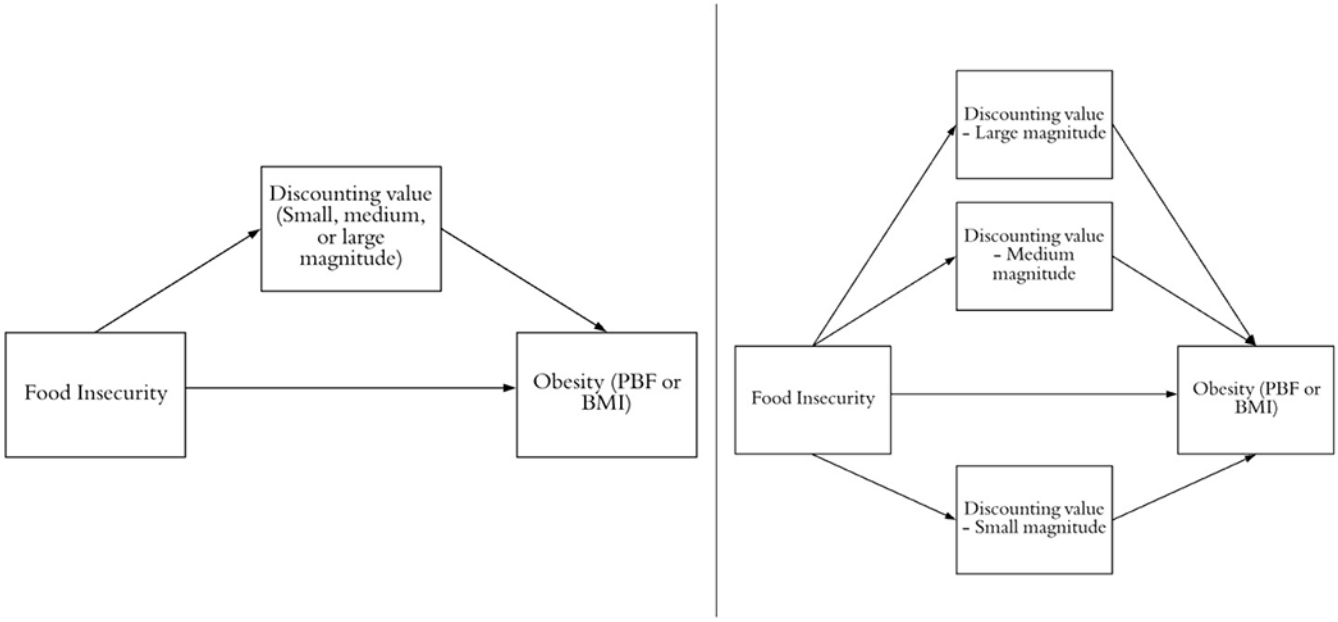

Figure 1.

Diagram of mediation analyses. The simple mediation analysis (left) is run with only one magnitude from each of the four discounting tasks predicting either to PBF or BMI. The parallel mediation analysis (right) would include all magnitudes of the specific choice predicting to PBF or BMI

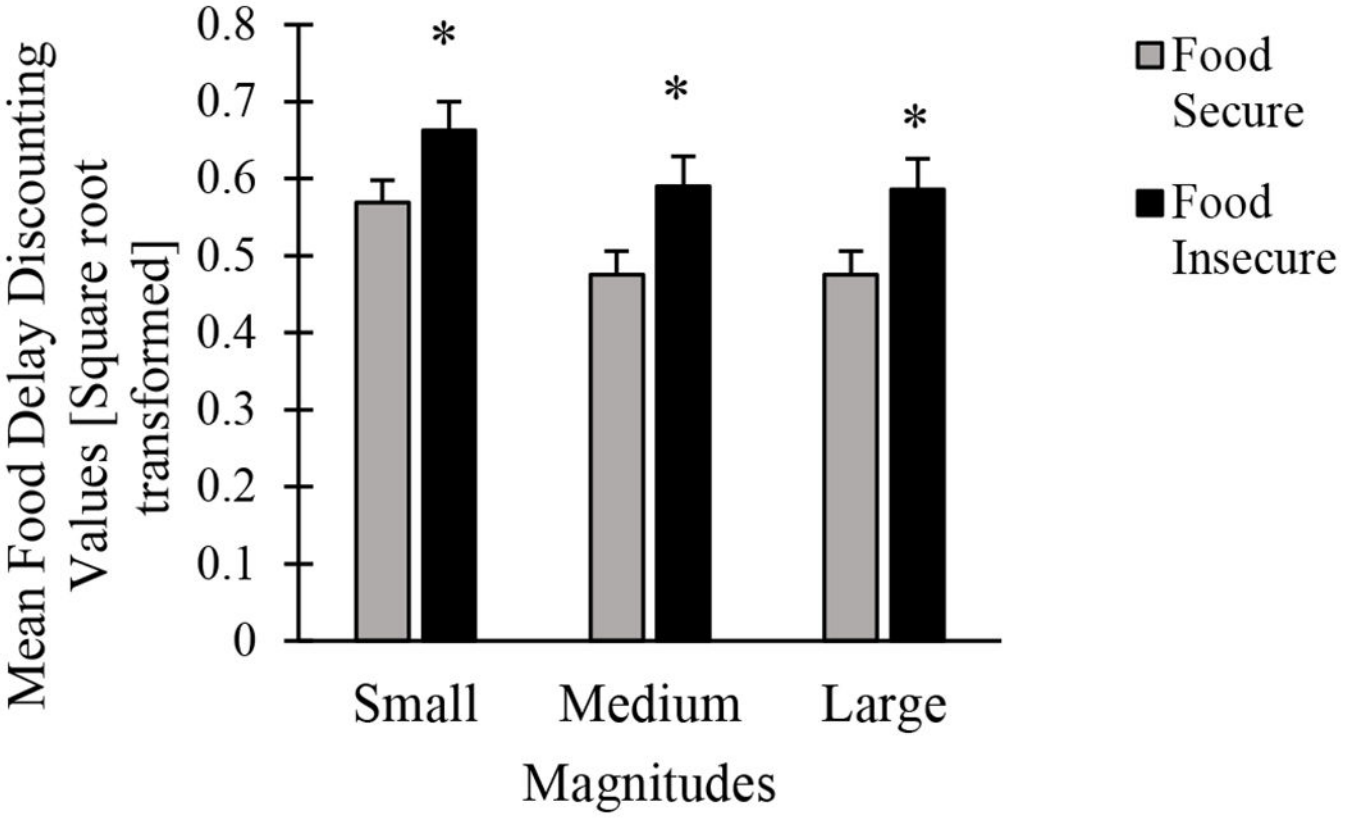

Figure 2.
Mean food DD values as a function of magnitude and food security status. Error bars = 1 SEM *p<0.05

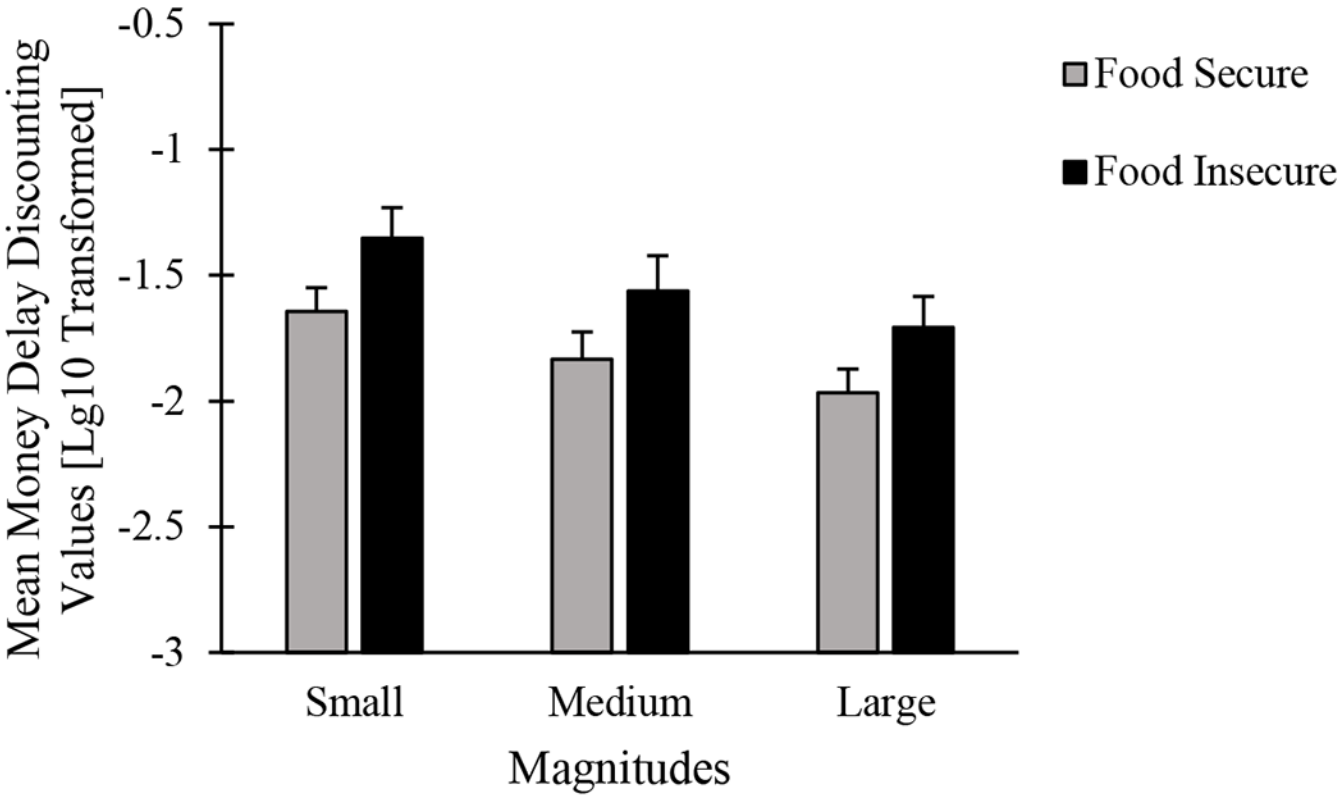

Figure 3.

Mean money DD values controlling for the effects of intellectual functioning and blood glucose as a function of magnitude and food security status. Analyses revealed no significant main effects or interactions for food security status and magnitude when including covariates. Error bars = 1 SEM

Table 1

Demographic Characteristics

	Total (N=92)	FI (n=35)	Food Secure (n=57)	*p*
	Mean (S.E.)	**Mean (S.E.)**	**Mean (S.E.)**	
Age (years)	40.5 (1.5)	43.7 (2.6)	38.5 (1.9)	0.10
Slosson Intell Test	96.9 (1.5)	91.8 (2.1)	100.0 (1.8)	0.006 *
%White #	78%	71%	83%	0.05
% Income <$20,000	45%	63%	33%	0.006 *
%Married #	41%	29%	49%	0.04 *
Time Since Last Paycheck (weeks ago)	2.4 (0.2)	2.7 (0.3)	2.3 (0.2)	0.27
Weight (kg)	81.0 (2.2)	84.6 (3.3)	78.8 (2.9)	0.20
BMI (kg/m^2)	29.8 (0.8)	31.8 (1.3)	28.6 (1.0)	0.03 *
% Body Fat	37.7 (1.0)	40.4 (1.3)	36.0 (1.3)	0.03 *
Waist Circumference (cm)	98.6 (2.2)	103.4 (3.1)	95.6 (3.0)	0.09
Subjective hunger (0–100)	36.3 (2.8)	35.2 (4.9)	36.9 (3.3)	0.76
Hours since last meal	9.5 (0.6)	10.5 (1.0)	8.9 (0.8)	0.23
Hours since last snack	6.8 (0.5)	7.7 (0.9)	6.3 (0.6)	0.22
Blood Glucose (mg/dL)	102.2 (3.5)	113.4 (8.5)	95.3 (1.8)	0.04 *
Alcohol Use Disorders Identification Test – C (AUDIT-C)	1.9 (0.2)	2.03 (0.4)	1.8 (0.3)	0.63
Drug Abuse Screening Test-10 (DAST-10)	1.3 (0.2)	1.3 (0.3)	1.4 (0.2)	0.83
Endorsed cigarette use	24%	31%	19%	0.19
Endorsed nicotine vape use	7%	7%	5%	0.53
BFFS - Fruits and Vegetables	13.3 (0.7)	11.3 (1.1)	14.6 (1.0)	0.03 *
BFFS - Dietary Fat	22.4 (0.8)	21.8 (1.5)	22.7 (1.0)	0.61
Perceived Stress Survey	17.3 (0.8)	20.1 (1.1)	15.5 (0.9)	0.003 *

Note.

largest group by percentage

* p<0.05