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Development and quantification of measures for risky and delayed food and monetary outcome choices

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ABSTRACT

Probability discounting (PD) measures risky choice patterns between smaller, more certain vs. larger, less certain outcomes. PD is associated with obesity as well as higher intake of foods high in fat and sugar. We developed and validated a brief PD task specifically for food-related choices–the Probabilistic Food Choice Questionnaire (PFCQ). We also validated a brief, existing PD monetary measure, the Probabilistic Monetary Choice Questionnaire (PMCQ) by comparing it to a titrating PD task. Participants (N = 110) were randomly assigned to either a food or money condition. Those assigned to the food condition completed the PFCQ and a more established, adjusting-amount PD task for hypothetical food outcomes. Those assigned to the money condition completed the PMCQ and a more established, adjusting-amount PD task. Participants also completed delay discounting (DD) tasks for the same outcome commodity. The PFCQ and adjusting-amount PD tasks strongly correlated across three magnitudes suggesting that the PFCQ may be a satisfactory and briefer measure for risky food choice. The PMCQ also showed significant correlations with the adjusting-amount monetary PD task, supporting its use for a brief measure of monetary discounting. For DD, the choice questionnaires demonstrated significant correlations with the adjusting-amount DD procedures, replicating previous research.

1. Introduction

Delay discounting (DD) is a measure of impulsivity that refers to the decrease in the subjective value of a reward as the delay to its receipt increases (Ainslie, 1975; Madden and Bickel, 2010; Rachlin et al., 1991). For example, individuals are presented with a series of smaller, immediate choices (e.g., $1 now) vs. larger, delayed (e.g., $10 in 1 day) outcomes. Choices are measured over a variety of different outcome amounts and delays (e.g., 10 days, 30 days, 1 year, 5 years, etc.). An individual who demonstrates relatively higher impulsive choice patterns would show a higher preference for the smaller, immediate outcomes relative to an individual who is more self-controlled.

The DD paradigm provides researchers and clinicians with an informative framework for understanding health-related behaviors such as cigarette smoking (Bickel et al., 1999; Friedel et al., 2014; Reynolds et al., 2004; Yi et al., 2007; Yi et al., 2016), opioid use (Kirby et al., 1999; Madden et al., 1997), and problematic gambling (Andrade and Petry, 2012; Holt et al., 2003; Madden et al., 2009). More recently, the DD paradigm has been used to examine factors that are related to obesity (Jarmolowicz et al., 2014; Weller et al., 2008). For example, obese individuals tend to prefer smaller, immediate amounts of food over larger, delayed amounts compared to their healthy-weight counterparts (e.g., Hendrickson and Rasmussen, 2013; Hendrickson et al., 2015; Rasmussen et al., 2010). Even a single food choice in early childhood (a la the marshmallow task) has been shown to predict obesity 30 years later (see Schlam et al. (2013)). Therefore, DD for food appears to be a fundamental behavioral process that underlies obesity.

One feature of the DD paradigm that researchers have tried to parse from the devaluing of a delayed outcome is the probability of its receipt. In other words, as delay to the outcome increases, the likelihood of receiving it also diminishes. For example, if someone was offered $100 tomorrow or after one year, not only would the value diminish with the delay, but the likelihood that an individual would receive it would also diminish. Because of this potential confounding variable, researchers have sought to determine the extent to which probability discounting and delay discounting are separate processes (see Green and Myerson, 2010, 2013; Rachlin et al., 1991).

Probability Discounting (PD), then, is the decrease in the subjective value of a reward as the odds to its receipt increase and has been identified as a measure of risky choice (Green and Myerson, 2010; Rachlin et al., 1991). Individuals are presented with the choice of receiving a larger, less certain outcome (e.g., $10 with a 90% chance of

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receiving it) vs. a smaller, certain outcome (e.g., $7 with a 100% chance of receiving it). With this particular choice, participants tend to show a riskier pattern of responding by selecting the larger, less certain outcome over the smaller, certain one. However, as the odds of receiving the larger reward decrease (in this case, $10 with a 75% chance of receiving it), a shift in an individual's pattern of responding occurs, such that s/he is more likely to select the smaller, certain outcome ($7 for sure).

While both PD and DD have been associated with numerous health outcomes (e.g., illicit drug use, alcohol use, smoking, obesity, etc.; MacKillop et al., 2011; Madden and Bickel, 2010; the relation between the two processes is unclear. Different "impulsive" groups tend to demonstrate differential preferences between delayed and risky rewards suggesting that sensitivity to delay and risk taking are separate facets of impulsivity (Green and Myerson, 2013). For instance, some individuals who tend to prefer certainty also prefer immediacy, while others who tend to prefer immediacy prefer uncertain rewards. These differences suggest that both probability discounting and delay discounting can be conceptualized as separate, distinct processes (Green and Myerson, 2013; Jarmolowicz et al., 2012), though related to the construct of impulsivity (Green and Myerson, 2013; Rachlin et al., 1991).

1.1. Brief measures of discounting: choice questionnaires

A typical method of establishing PD is the adjusting-amount procedure in which participants select between two concurrently available options: a smaller, certain reward (e.g., $5 for sure) or a larger, less certain reward (e.g., 25% chance of receiving $10). The smaller, certain outcome is adjusted systematically until the individual switches from the smaller, certain outcome to the larger, less certain outcome (i.e., preference reversal). These preference reversals are used to determine the current subjective value of the larger, less certain reward or indifference points. Indifference points can be plotted against probabilities for larger, less certain outcomes (e.g., 0.9, 0.75, 0.5), which is often converted first to the odds against receiving it ($[1/p] - 1$; p = probability of receiving). The value of the larger, less certain outcome decreases in value in a hyperbolic manner as the odds against receiving it increase. For delay discounting, the procedure is similar, except choices are between smaller, sooner vs larger later options. A similar hyperbolic pattern is observed in the value of the delayed reward as delay to its receipt increases (e.g., from one day to one month; Mazur, 1987; Rachlin et al., 1991).

A number of studies employing the adjusting-amount procedure use computerized programs. There are a number of strengths with these methods, especially the Richards et al. (1999) task that includes a titration procedure that systematically increases or decreases amounts based on the participant's individualized choice patters, randomized presentation of choices, and the use of an unpredictable algorithm that not only disguises the nature of the task, but also re-presents questions that result in inconsistent responses. However, the one drawback is that these methodological strengths may result in the task taking a longer time to complete, for example, some participants may take up to 20 min (see Hendrickson and Rasmussen, 2013, 2017). This may be problematic with certain populations, such as children (Hendrickson & Rasmussen, 2017) or when research protocols are longer and participant fatigue is likely.

One common approach to establishing discounting patterns in a short period of time is to use choice questionnaires. The Monetary Choice Questionnaire (MCQ; Kirby and Marakovic, 1996; Kirby et al., 1999) is a well-established example. The MCQ is a 27-item measure that estimates an individual's pattern of delay discounting based upon predetermined discounting values derived from Mazur's (1987) hyperbolic equation. More recently, the Food Choice Questionnaire (FCQ; Hendrickson et al., 2015), which was patterned after the MCQ, estimates food discounting in a manner similar to the adjusting-amount food discounting procedure. The MCQ and FCQ have several advantages: One, they are brief in terms of administration and scoring time, which is often about 5 min. Two, the discounting values derived from them are strongly correlated with discounting measures from computerized and titrating procedures (Epstein et al., 2003; Hendrickson et al., 2015). Three, there is an opportunity to estimate discounting rates across a range of three reward magnitudes, which is a benefit because there is a robust literature showing that the degree of discounting for money (e.g., Amlung and MacKillop, 2011; Estle et al., 2006; Kirby and Marakovic, 1996*), food* (Hendrickson et al., 2015; Odum et al., 2006), as well as other commodities (e.g., Baker et al., 2003; Greenhow et al., 2015; Weatherly and Terrell, 2014) is inversely related to the outcome magnitude. (This is termed the "magnitude effect".)

Despite the number of studies that use probability discounting as measures of risky choice (e.g., Ohmura et al., 2006; Rasmussen et al., 2010; Reynolds et al., 2004), there are few choice questionnaires that have been used with probability discounting. One exception is a measure developed by Madden et al. (2009) called the Probabilistic Monetary Choice Questionnaire (PMCQ), which to our knowledge, has not yet been validated against a previously established probability discounting task.

Brief measures of probability discounting for other outcomes could have strong utility. For example, not only are obese individuals more impulsive for food, but they also have been shown to be risk-averse for food with titrating probability discounting tasks (Rasmussen et al., 2010). In addition, greater calorie consumption has been linked to increased gambling behavior (Chamberlain et al., 2017) suggesting that one's sensitivity to risk may play a role in eating behavior. Therefore, it would be important to have a brief measure of probability discounting for food to further examine underlying processes of eating behavior.

1.2. Purpose of study

The purpose of the current study was to establish a brief, easy-to-administer alternative measure of food probability discounting, the Probabilistic Food Choice Questionnaire (PFCQ), and validate it against a previously established computerized probability discounting task for food (Rasmussen et al., 2010; Richards et al., 1999). This would provide a companion measure to the more recently established Food Choice Questionnaire (FCQ; Hendrickson et al. 2015), a measure of impulsivity for food outcomes. Together, these alternative methods of discounting would allow for quicker assessment of food discounting patterns in situations where time and resources are a limiting factor. Additionally, we validated the use of the Probabilistic Monetary Choice Questionnaire (PMCQ; Madden et al., 2009) against an already established computerized monetary discounting task (Richards et al., 1999). For purposes of replicability, participants also completed either the FCQ or MCQ, which was compared to the computerized delay discounting task. Our main hypotheses were: 1) Probability discounting rates on the PFCQ and computerized food discounting task would significantly correlate; 2) Discounting rates from the PMCQ and computerized monetary probability discounting task would significantly correlate. We also expected to replicate previously established relations with discounting tasks and magnitude effects (e.g., Greenhow et al., 2015; Hendrickson et al., 2015). Specifically, delay discounting rates would decrease as reward magnitudes increased, whereas probability discounting rates would increase as reward magnitudes increased.

2. Material and methods

2.1. Participants

Participants ($N = 110$, 67 female) were undergraduate students enrolled in psychology courses from Idaho State University and recruited via SONA, an online subject pool ($M_{age} = 21.2$, $SD = 4.73$). Inclusion criteria were: current undergraduate status, 18 years of age or older, abstention from eating food four hours prior to participation, and drinking liquid two hours prior to participation. Exclusion criteria were: pregnancy, a diagnosed or suspected eating disorder, or participation in another food discounting study. Each participant was randomly assigned to either a food (n = 57) or the money (n = 51) condition.

2.2. Measures

2.2.1. Demographic information

Participants provided information regarding basic demographic and health variables (e.g., age, gender, socioeconomic status, activity level), and nicotine dependence.

2.2.2. Drug and alcohol screening

The Drug Abuse Screening Test (DAST-10; Skinner, 1982) and Alcohol Use Disorders Identification Test (AUDIT-C; Bush et al., 1998) are self-report measures that assess an individual's current substance use and level of impairment over the past year. On both measures, higher scores indicate a greater degree of problems or consequences related to illicit substances or alcohol, respectively. On the DAST-10, scores greater than 0 indicate some degree of problems related to drug abuse. Scores of 1–2 indicate low level, 3–5 indicate moderate level, 6–8 indicate substantial level, and scores of 9–10 indicate severe level of problems related to drug abuse. On the AUDIT-C, scores of 3 or more for women and scores of 4 or more for men indicate a positive screen for hazardous or problem drinking. These measures were used to control for excessive drug and alcohol use—two factors that are known to influence delay discounting rates (e.g., Kollins, 2003; Petry, 2001). If both the choice questionnaires and adjusting amount procedures showed similar associations with drug and alcohol use, this would provide further evidence that both measures assessed similar processes (Epstein et al., 2003).

2.2.3. Subjective hunger questionnaire

The subjective hunger questionnaire (Hendrickson and Rasmussen, 2013; Rasmussen et al., 2010) is a self-report measure that was used to control for potential food intake before the session. Participants reported time since their last snack and full meal, as well as rate their current hunger level on a scale of 0–100 (0 = not hunger at all, 100 = very hungry).

2.2.4. Probabilistic choice questionnaires

The probabilistic choice questionnaires included the Probabilistic Monetary Choice Questionnaire (PMCQ; Madden et al., 2009) and the novel Probabilistic Food Choice Questionnaire (PFCQ), adapted from the Monetary Choice Questionnaire (MCQ; Kirby and Marakovic, 1996; Kirby et al., 1999), and the Food Choice Questionnaire (FCQ; Hendrickson et al., 2015), respectively. Both measures used predetermined discounting values already established for each set of choices for probabilistic monetary (PMCQ) or probabilistic food outcomes (PFCQ).

The PFCQ (Table 1) presents 39 choices between hypothetical bites of smaller, certain food outcomes vs. larger, less certain ones. There are 13 questions total for each magnitude; however, though only 11 questions assess discounting for each of small (8–14 bites), medium (26–36 bites), and large (40–50 bites) magnitudes. In addition, two types of questions were added to each magnitude to assess for sensitivity to amount (those with asterisks) and random responding (those with carets). Sensitivity to amount was assessed by presenting participants with a smaller reward and a larger reward that was available without risk on the probability choice questionnaires. For example, on the PFCQ, participants chose between four bites for sure and a 100% chance of receiving 14 bites. Assessing sensitivity to amount is important because an individual whose behavior is averse to larger amounts of a reward might exhibit preference for the smaller amount regardless of the delay or probability, which would artificially inflate his or her discounting scores (see Paglieri et al., 2015). Questions to assess random responding were added to the PFCQ and the PMCQ such that participants were offered a choice between a smaller, for sure amount and a larger, unavailable amount. For example, "Would you prefer 13 bites for sure or a 0% chance of receiving 26 bites?" Neither type of questions had pre-determined discounting values and are not included in determining discounting rates. (Though these latter questions are marked with asterisks and carets in the table below, they were not marked in the actual measure.)

Participant h values (i.e., probability discounting values) for the PFCQ were determined by using data from a previously published dataset to avoid basal or ceiling effects (Hendrickson and Rasmussen, 2013). A discounting value was obtained for each magnitude using scoring procedures described in Kirby and Marakovic (1996) and Kirby et al. (1999; see below for more details on scoring choice questionnaires). Participants completed the PMCQ in a similar manner and selected between three sets of smaller, certain vs. larger, less certain outcomes that remained stable with varying probabilities ($20 vs. $80; $40 vs. $100; $40 vs. $60; for more specific details regarding the values of the PMCQ, see Madden et al. (2009)).

Table 1
Probabilistic Food Choice Questionnaire trials arranged in ascending order according to magnitude and predetermined discounting valued.

Order	Certain Amount	Probabilistic Amount	Probability of Receiving Larger	h values
Small Magnitude (8–14 bites)				
35[a]	4	8	0	–
8	5	10	0.1	0.1111
5	6	12	0.18	0.2195
3	7	14	0.25	0.3333
1	4	8	0.38	0.6129
38	5	10	0.44	0.7857
34	6	12	0.5	1.0000
12	7	14	0.63	1.7027
31	4	8	0.75	3.0000
20	5	10	0.83	4.8824
28	6	12	0.92	11.5000
24	7	14	0.95	19.0000
15[b]	4	14	1	–
Medium Magnitude (26–36 bites)				
4[a]	13	26	0	–
37	14	28	0.1	0.1111
22	15	30	0.18	0.2195
26	16	32	0.25	0.3333
16	17	34	0.38	0.6129
9	18	36	0.44	0.7857
2	13	26	0.5	1.0000
32	14	28	0.63	1.7027
30	15	30	0.75	3.0000
33	16	32	0.83	4.8824
25	17	34	0.92	11.5000
10	18	36	0.95	19.0000
18[b]	13	36	1	–
Large Magnitude (40–50 bites)				
17[a]	20	40	0	–
21	21	42	0.1	0.1111
29	22	44	0.18	0.2195
23	23	46	0.25	0.3333
36	24	48	0.38	0.6129
27	25	50	0.44	0.7857
11	20	40	0.5	1.0000
6	21	42	0.63	1.7027
19	22	44	0.75	3.0000
14	23	46	0.83	4.8824
7	24	48	0.92	11.5000
39	25	50	0.95	19.0000
13[b]	20	50	1	–

[a] These trials have no assigned discounting value and were not included in measurement of discounting, but assessed participant attention.
[b] These trials have no assigned discounting value and were not included in measurement of discounting, but assessed participant sensitivity to amount.

2.2.5. Delay choice questionnaires

The Monetary Choice Questionnaire (MCQ; Kirby and Marakovic, 1996; Kirby et al., 1999) and the Food Choice Questionnaire (FCQ; Hendrickson et al., 2015) are previously established measures that assess discounting of either delayed food or delayed monetary outcomes, respectively, across small, medium, and large magnitudes (see Hendrickson et al. (2015) and Kirby et al. (1999) for more detail on FCQ and MCQ values, respectively). Participants completed the questionnaires in a similar manner as the probabilistic choice questionnaires. Both measures had sensitivity to amount questions added, similar to those on the PFCQ and PMCQ for each of the magnitudes of both the FCQ and MCQ (e.g., “Would you prefer 4 bites now OR 13 bites in 0 h?” “Would you prefer $11 now OR $35 in 0 days?”). No random responding questions were added to either the FCQ or MCQ.

2.2.6. Adjusting amount discounting tasks

The adjusting amount (AA) discounting tasks were completed on a desktop computer and used a procedure described by Richards et al. (1999) to determine indifference points across various delays and probabilities for food or monetary outcomes. The adjusting amount procedure for food (AA-F) was a computerized tasks with probability and delayed trials interspersed with one another to study risk-averse and impulsive behavior for food (Hendrickson and Rasmussen, 2013; Hendrickson et al., 2015; Rasmussen et al., 2010). The task consisted of approximately 110 questions with the exact number for each participant determined by his or her consistency in responding. The smaller, certain and larger, less certain options randomly switched from the top or bottom of the computer screen. Upon selection of the preferred choice, participants confirmed their response in a box that asked, “Are you sure?” Selecting “yes” would result in the presentation of the next trial, and selecting” no” would present the same choice again. The placement of “yes” and “no” appeared in a random manner on the left and right side of the screen to discourage inattentive or random responding. The immediate option adjusted ± 0.50 bites dependent upon the previous response of the participant. The program would continue to adjust the smaller, sooner amount up or down using a range of values determined by previous responses to help reduce the number of questions presented. The algorithm presented questions in a pseudorandom order, therefore decreasing the predictability of the adjusted values across trials. The task automatically ended once indifference points were established for each delay (1, 2, 5, 10, and 20 h) and probability (0.90, 0.75, 0.50, 0.25, and 0.10). For the AA procedure for money (AA-M), the task was similar to the AA-F, except participants selected between smaller, sooner amounts of money (e.g., $3 now) or a larger, later amounts (e.g., $10 in 180 days) across a range of delays (1, 2, 30, 180, or 360 days) and probabilities (0.90, 0.75, 0.50, 0.25 and 0.10). For an overview of all discounting measures used see Table 2.

Epstein et al. (2003) demonstrated strong associations between discounting values obtained from the adjusting amount procedure and choice measures such as the MCQ. In addition, both delay discounting tasks showed similar associations to other related variables (e.g., nicotine use and education) suggesting they measure similar choice processes but are not necessarily interchangeable. Similar results were later found with the FCQ and adjusting amount procedure for food (Hendrickson et al., 2015).

2.3. Procedure

Participants completed the study individually in an office-size room. If participants reported they had not consumed food or drink for more than four and two hours, respectively, they completed the informed consent process and participated in the study. Research assistants rescheduled those who did not meet the deprivation requirement. Participants completed the Subjective Hunger Questionnaire, followed by the discounting tasks. Participants were assigned to complete either the food discounting tasks (FCQ, AA-F for delay and probability discounting, and the PFCQ) or the money discounting tasks (MCQ, AA-M for delay and probability monetary discounting, and PMCQ).

For those in the food discounting condition, prior to beginning the food discounting measures, instructions directed participants to a 5/8″ white cube placed in front of them. The instructions asked participants to imagine the cube as one bite of their favorite kind of food. This cube standardized bites across participants. They were not required to report their choice for food. Order of the adjusting amount tasks and choice questionnaires was counterbalanced across participants.

For the adjusting amount procedure and the choice questionnaires, participants sat in a cubicle with a single desktop computer. Depending on the assigned condition (food or money), researchers presented participants with a script to read for either the AA-M or the AA-F. The AA-F wording is presented in brackets:

> In the task that follows, you will have the opportunity to choose between different amounts of money [food] available after different delays and probabilities. [Imagine that this block in front of you is one bite of your favorite kind of food. We would like you to make your decisions as if what you would eat would be your favorite kind of food and as if the only options you had to choose from would be those available in the question]. The test consists of questions such as the following, “would you rather have $3 [2 bites] now, or $10 [10 bites] in 30 days [10 h]?” or “would you rather have $3 [2 bites] for sure, or $10 [10 bites] with a 50% chance.” You will not receive the reward you choose, but we want you to make your decision as though you were actually going to receive the reward.

Before the completion of the PMCQ or PFCQ, participants read the following instructions (food wording is in brackets):

> In the task that follows, you will have the opportunity to choose between reward [food] amounts after different probabilities. [For this task, imagine the block in front of you as 1 standardized bite of your favorite food. Answer the questions as if what you would eat would be your favorite kind of food and as if the only options you

Table 2
List of probability and delay discounting measures used in current study.

Discounting Measure	Magnitude	Range of Probability or Delay	Range of Larger Reward Amount
Probabilistic Food Choice Questionnaire (PFCQ)	Small Medium Large	0–100% 0–100% 0–100%	8–14 bites 26–36 bites 40–50 bites
Probabilistic Monetary Choice Questionnaire (PMCQ)[a]	Small Medium Large	0–100% 0–100% 0–100%	$80 $100 $60
Adjusting Amount Procedure – Food Probability (AA-F)		10%–90%	10 bites
Adjusting Amount Procedure – Money Probability (AA-M)		10%–90%	$10
Food Choice Questionnaire (FCQ)[a]	Small Medium Large	0–24 h 0–23 h 0–24 h	8–13 bites 25–35 bites 40–50 bites
Monetary Choice Questionnaire (MCQ)[a]	Small Medium Large	0–186 days 0–160 days 0–162 days	$25–$35 $50–$60 $75–$85
Adjusting Amount Procedure – Food Delay (AA-F)		1–20 h	10 bites
Adjusting Amount Procedure – Money Delay (AA-M)		1–360 days	$10

[a] Questions for assessing sensitivity to amount and random responding were added for the current study and were not previously included in the measures initial development.

would have to choose from would be those in the question]. You will not receive the rewards that you choose, but we want you to make your decisions as though you were really going to get them. Please take the choices seriously. The reward choices are written on this form. Circle your reward choice for each question and answer every question as though you will actually receive that choice. The choices you make are up to you.

Researchers presented similar instructions prior to the FCQ or MCQ (see Hendrickson et al. (2015). After acknowledging they had read the instructions, participants answered the individually-presented questions on a computer screen. Options for the smaller, certain amount and larger, probabilistic amount switched between the left and right sides of the computer screen for each question.

After the discounting tasks were completed, the demographics questionnaire was administered. Lastly, biometric measurements were collected. To measure height, participants removed shoes and socks, and stood by a wall with a measuring tape. For weight and percent body fat, participants stepped backwards onto a Tanita® scale. The body mass index (BMI) for each participant was calculated by dividing the individual's weight in kilograms by their height in meters squared (kg/m^2). Following the completion of the biometric data, participants completed a research experience questionnaire, which queries about whether any of the procedures made the participant uncomfortable. Participants received course credit for their participation. The Institutional Review Board (IRB) of Idaho State University approved all procedures.

2.4. Adjusting-amount discounting values

The hyperbolic equation ($V = A/[1 + h\theta]$; e.g., Mazur, 1987) was fit to each participant's indifferent points using non-linear regression to establish individual h values (i.e., a free parameter that indexes one's rate of discounting) for the probability discounting tasks. In the hyperbolic equation, V is equal to the subjective value of the reward (i.e., indifference points), A is the amount of the large reward, θ is equal to odds against ($[1/p] - 1$; p = probability of receiving) receiving the larger, less certain reward for probability discounting. For delay discounting, the equation is similar, except the free parameter h is referred to as k, and θ is substituted for D, which represents the delay to the receipt of the larger, later reward. The parameter h was used as the dependent variable in the probability discounting analyses, whereas the parameter k was used as the dependent variable in the delay discounting analyses.

Area under the curve values (AUC; Myerson et al., 2001) were calculated with each participant's discounting curves to provide an atheoretical measure of discounting. AUC values are bound between 0 and 1 and typically are more normally distributed relative to h and k values (see Borges et al. (2016)). An AUC value closer to 0 is indicative of behavior that is highly risk averse (probability discounting) or impulsive (delay discounting), while values closer to 1 are indicative of behavior that is less risk averse or more self-controlled, respectively.

We used Johnson and Bickel's (2008) algorithm to determine the orderliness of the AA-M and AA-F data. An individual was labeled as "nonsystematic" if any indifferent point, starting with the second point, was greater than preceding indifference point by 20% of the larger, delayed or less certain outcome or more, and/or if the last indifferent point was not less than the first indifference point by at least 10% of the larger, delayed or less certain outcome. The frequency of nonsystematic responders was used for descriptive purposes only; all data, whether systematic or not, were used in the analyses. Exclusion of nonsystematic responders did not impact the results.

2.5. Choice questionnaires scoring

All estimated discounting values from the four choice questionnaires were determined by the pattern of responses made by the participant across each of the questionnaires. For example, for the PFCQ (see Table 1), the predetermined h value associated with each question defined the range of an individual's estimated discounting rate within each of the three different magnitudes (e.g., small, medium, and larger). Selection of the smaller reward or the larger less certain (or delayed) reward narrowed the range of the estimated discounting rate for each participant. For example, on the PFCQ, the first trial of "4 bites for sure or a 38% chance of receiving 8 bites" has 0.6129 as the predetermined discounting value. An individual with a discounting rate of 0.6129 would be "indifferent" between the two rewards presented in the trial and would select either the smaller or the larger reward approximately 50% of the time. Thus, an individual with a discounting rate greater than 0.6129 would select the smaller, for sure reward (e.g., 4 bites for sure), while an individual with a discounting rate less than 0.6129 would select the larger, less certain outcome (e.g., 38% chance of receiving 8 bites). The point at which the participant switches from the larger, less certain outcome to the smaller, for sure outcome defines the upper and lower bounds of the range. The geometric mean is used to calculate the midpoint between the two bounds. This midpoint represents the discounting value for that specific magnitude. Each predetermined h or k value within a magnitude is associated with a single switch occurring at a specific point from the larger uncertain or delayed reward to the smaller reward. Individuals who demonstrate this pattern are considered consistent responders, whereas individuals who show switches from the larger reward to the smaller reward more than one time are deemed inconsistent. For individuals who demonstrated inconsistent responding (i.e., multiple switches between the smaller, certain amount and the larger, less certain amount), the geometric mean of the most similar pattern of consistent responding was used. If more than one consistent pattern was similar, we used the geometric mean of those two values (see Kirby and Marakovic (1996) and Kirby et al. (1999) for more detail on measures, parameter estimation, and response consistency procedures for the MCQ, Hendrickson et al. (2015), for the FCQ, and Madden et al. (2009) for the PMCQ). Both inconsistent and consistent responders were included in analyses and the information is presented for descriptive purposes only. Exclusion of inconsistent responders did not impact the results.

2.6. Statistical analysis

The data were analyzed using SPSS 23 and GraphPad Prism statistical software. Discounting rates were not obtained from two participants in the food group due to an administration error and were therefore not included in analyses; therefore, only the data from 108 participants are included.

Due to skewness of discounting data (see Table 3), which is common in discounting studies (e.g., Bickel et al., 1999; Borges et al., 2016; Dixon et al., 2003; Madden et al., 1997, 2009), the h values, k values, and AUCs from the adjusting amount procedure for food and money were transformed using log10 transformation. Similarly, h values from the PFCQ and PMCQ were also log10 transformed. k values from all magnitudes of the MCQ and the medium and large magnitudes of the FCQ were transformed using square root transformations. The small magnitude k values of the FCQ did not require transformation. First, chi-square and independent samples t-tests were used to test for differences amongst demographic variables. Next, Pearson's r correlations were conducted between discounting values of each discounting task and used to calculate the relation between discounting values, demographic information (e.g., age, income), time since last snack, time since last meal, subjective hunger, substance use and alcohol use variables, and weight-status variables (e.g., weight, percent body fat, BMI). Third, a repeated-measures ANOVA was used to determine differences between magnitudes of the choice questionnaires.

Table 3
Skewness values and standard error for each discounting task and magnitude.

Discounting Task	Skewness (S)	Standard Error (S_s)
AA-F (delay) k value	6.18	0.32
AA-F (delay) AUC	1.67	0.32
AA-F (probability) h value	3.53	0.32
AA-F (probability) AUC	1.39	0.32
PFCQ – Large Magnitude	1.11	0.32
PFCQ – Medium Magnitude	1.36	0.32
PFCQ – Small Magnitude	1.65	0.32
FCQ – Large Magnitude	0.32	0.32
FCQ – Medium Magnitude	0.47	0.32
FCQ – Small Magnitude	−0.17	0.32
AA-M (delay) k value	5.57	0.33
AA-M (delay) AUC	1.03	0.33
AA-M (probability) h value	5.60	0.33
AA-M (probability) AUC	0.62	0.33
PMCQ – Large Magnitude	2.54	0.33
PMCQ – Medium Magnitude	2.95	0.33
PMCQ – Small Magnitude	1.76	0.33
MCQ – Large Magnitude	2.02	0.33
MCQ – Medium Magnitude	1.59	0.33
MCQ – Small Magnitude	0.87	0.33

3. Results

3.1. Demographics

Participant demographic information, excluding two participants, is described in Table 4. There were no significant differences in demographic information between the food and money conditions.

3.2. Probability discounting

3.2.1. Orderliness of data

For the AA-F probability discounting task, approximately 84% of the participants in the food condition and 92% of participant in the AA-M condition demonstrated systematic responding on the adjusting amount probability discounting task. Median goodness-of-fit values for all participant data were $R^2 = 0.99$ for food and $R^2 = 0.98$ for money (see Fig. 1).

Table 4
Means and standard deviations of health variables for total sample and across conditions.

	Total (N = 108) Mean (SD)	Food Condition (n = 57) Mean (SD)	Money Condition (n = 51) Mean (SD)	
Age	21.22 (4.73)	21.67 (5.78)	20.73 (3.14)	*ns*
Female*	67%	68.4%	54.9%	*ns*
Caucasian*	75%	78.9%	70.6%	*ns*
Income > $70,000*	22%	22.8%	21.6%	*ns*
Subjective hunger	58.39 (23.94)	60.75 (23.03)	55.75 (24.88)	*ns*
Time since last meal (hours)	11.03 (4.59)	10.63 (5.01)	11.46 (4.09)	*ns*
Time since last snack (hours)	8.58 (3.85)	8.36 (4.01)	8.83 (3.68)	*ns*
Weight (kg)	72.91 (16.16)	70.74 (13.92)	75.33 (18.17)	*ns*
Body mass index	25.18 (4.68)	24.70 (4.28)	25.72 (5.09)	*ns*
Percent body fat	26.43 (9.99)	26.4 (10.29)	26.47 (9.74)	*ns*
Waist circumference (cm)	84.27 (12.84)	82.72 (12.05)	86.00 (13.59)	*ns*
AUDIT-C positive screen	46%	44%	36.8%	*ns*
DAST-10				
Low Level	69%	65%	65%	*ns*
Moderate Level	16%	16%	14%	*ns*
Substantial Level	1%	2%	0%	*ns*

Note. *Largest group by percentage.

For the PFCQ, most participants demonstrated a consistent pattern of responding across the small (99%), medium (98%), and large (98%) magnitudes respectively. Participants demonstrated similar consistency on the PMCQ, 99% across all three magnitudes.

3.2.2. Tests for amount sensitivity and random responding

On the PFCQ amount sensitivity questions, 95% of participants selected the larger, certain outcome over the smaller, certain outcome for the small magnitude, 97% for the medium magnitude, and 90% for the large magnitude. For the random responding questions, nearly all participants selected the smaller, certain outcome over the larger, unavailable outcome (100% for small and large magnitudes, 98% for medium magnitude).

On the PMCQ, 100% of participants selected the larger, certain outcome of the amount sensitivity questions across all probability pairings. Ninety-eight to one-hundred percent of participants selected the small, certain outcome on the random responding questions across all three magnitudes.

Analyses of discounting values were conducted with and without those who selected either the smaller outcome on the amount sensitivity questions and/or the large unavailable reward of the random responding question. Results remained similar with or without these types of responders. Therefore, all participants' data, regardless of responses on sensitivity to amount and random responding questions, were included in the analyses.

3.2.3. PFCQ and AA-F for probability discounting

Fig. 2 shows the mean discounting rates of the probability adjusting amount procedure and the three magnitudes of the PFCQ.

Pearson's correlations (Table 5) indicate strong, significant correlations between h values from the probability AA-F and the three magnitudes of the PFCQ. AUC values were also inversely related to discounting rates from the PFCQ. The three magnitudes of the PFCQ significantly correlated with one another. A repeated-measures ANOVA revealed a significant difference between magnitudes of the PFCQ ($F (2112) = 3.55$, $p = 0.03$) indicating a magnitude effect. Post-hoc analyses using least squared difference (LSD) revealed a significant difference between the small and large magnitude ($p = 0.02$) but no significant differences between the small and medium or medium and large magnitudes respectively.

The large magnitude of the PFCQ was significantly and positively related to percent body fat ($r = 0.27$, $p = 0.045$), but this was not observed across the remaining magnitudes. No significant relations were observed between the PFCQ and other weight-status variables (e.g., BMI, weight, waist, etc.), consumption variables (i.e., subjective hunger, time since last snack, time since last meal), substance- and alcohol use variables, or demographic variables (e.g., gender, ethnicity, income, etc.).

3.2.4. PMCQ and AA-M for probability discounting

Fig. 3 shows the mean discounting rates of the probability adjusting amount procedure and the three magnitudes of the PMCQ.

Pearson's correlations (Table 6) show significant positive relations between h values from the probability AA-M and two of the three value ranges of the PMCQ: $20 vs. $80 and $40 vs. $100. Similarly, AUC demonstrated significant inverse relations with h values from the $20 vs. $80 and $40 vs. $100 conditions. Values from the adjusting amount procedure and AUC showed no significant relation with the $40 vs. $60. The three magnitudes were significantly correlated with one another, but did not differ from one another ($p = 0.13$).

Weight significantly correlated with discounting values from the $40 vs. $60 value range of the PMCQ ($r = 0.32$, $p = 0.02$) as did BMI ($r = 0.31$, $p = 0.03$). No other significant relations were observed between weight-status variables and the remaining magnitudes of the PMCQ or the AA-M. The PMCQ and the AA-M did not significantly correlate with any consumption, substance use, alcohol use, or demographics variables.

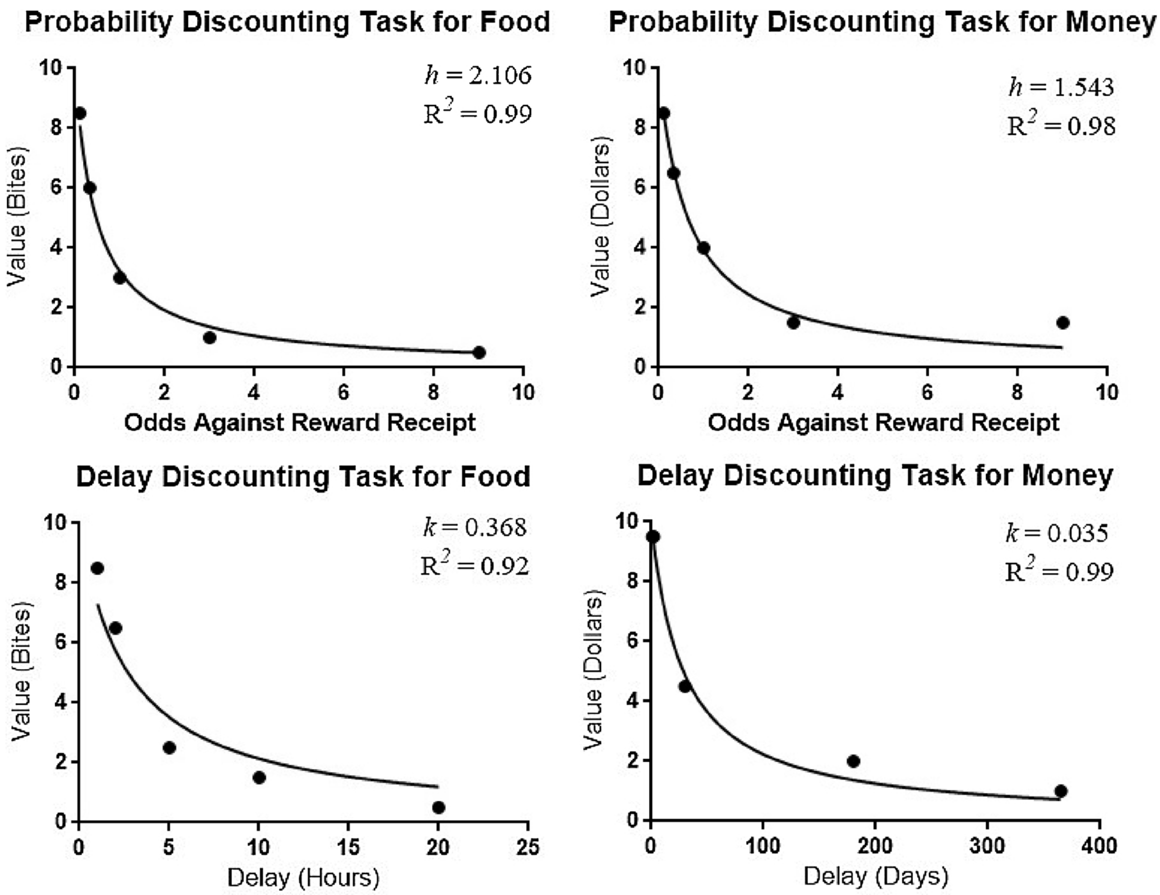

Fig. 1. Median indifference values as a function of probability (top) and delay (bottom) for all participants using the adjusting amount (AA) procedure. Fit lines represent best fit of the hyperbolic function. In some cases, two data points overlapped at short delays for money.

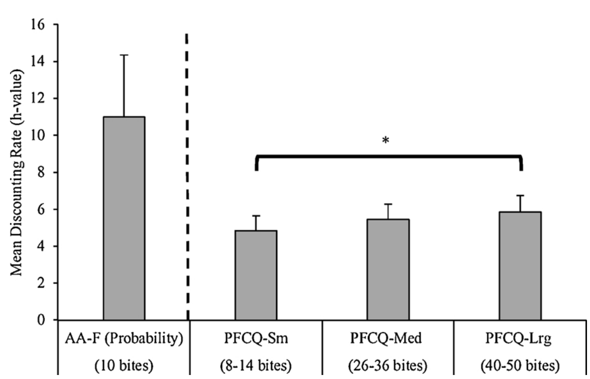

Fig. 2. Mean discounting values across the probability adjusting amount procedure and the small, medium, and large magnitude of the Probabilistic Food Choice Questionnaire (PFCQ). AA-F represents data from the Adjusting Amount computerized task for food. Error bars represent 1 SEM. *$p < 0.05$.

3.3. Delay discounting

3.3.1. Orderliness of data

Approximately 83% of participants in the AA-F delay discounting and 98% of participants in the AA-M delay discounting task demonstrated systematic responding. Median goodness-of-fit values were $R^2 = 0.92$ for food outcomes and $R^2 = 0.99$ for monetary outcomes (see Fig. 1). Average consistency values on the FCQ were 94% for the small magnitude and 95% for the medium and large magnitudes. On the MCQ, consistency values were 100% for the small magnitude and 99% for the medium and large magnitudes.

Table 5
Pearson's Correlations among Different Measures of Probability Discounting for Food.

Variables	1	2	3	4
1 PFCQ (lg10[h]) small	–			
1 PFCQ (lg10[h]) medium	0.91**	–		
1 PFCQ (lg10[h]) large	0.89**	0.91**	–	
1 AA-F *h* (lg10[h])	0.74**	0.75**	0.66**	–
1 AA-F AUC (lg10[AUC])	−0.61**	−0.65**	−0.63**	−0.79**

Note. PBF = Percent Body Fat, AA-F = Adjusting Amount Food, AUC = Area Under the Curve.
*$p < 0.05$.
** $p < 0.01$.

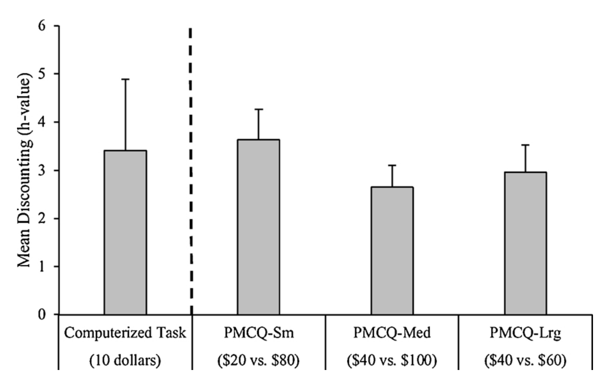

Fig. 3. Mean discounting values across the probability adjusting amount procedure and the small, medium, and large magnitude of the Probabilistic Monetary Choice Questionnaire (PMCQ). Error bars represent 1 SEM.

Table 6
Pearson's Correlations among the Different Measures of Probability Discounting for Money.

Variables	1	2	3	4
1 PMCQ (lg10[h]; \$20 vs. \$80)	–			
1 PMCQ (lg10[h]; \$40 vs. \$100)	.74**	–		
1 PMCQ (lg10[h]; \$40 vs. \$60)	.41*	.65**	–	
1 AA-M h (lg10[h])	.34**	.31**	.21	–
1 AA-M AUC (lg10[AUC])	−.42**	−.37**	−.10	−.89**

Note. AA-M = Adjusting Amount Money, AUC = Area Under the Curve.
* $p < 0.05$.
** $p < 0.01$.

3.3.2. Sensitivity to amount questions

For the amount sensitivity questions of the FCQ, 88%, 86%, and 84% of participants selected the larger, non-delayed outcome for the small, medium, and large magnitudes, respectively. For the small and medium magnitude MCQ, 82% of participants selected the larger, non-delayed outcome, whereas 80% of participants made a similar choice on the large magnitude

Analyses with and without those who selected the smaller available reward relative to the larger available reward revealed no changes in the results; therefore, all participants were included in subsequent analyses.

3.3.3. FCQ and AA-F delay discounting

Fig. 4 displays the mean discounting values of the delay adjusting amount procedure and the three magnitudes of the FCQ.

Machley's test revealed the assumption of sphericity had been violated ($\chi^2(2) = 22.14$, $p < 0.001$), therefore Greenhouse-Geisser corrected tests are reported. The repeated-measures ANOVA indicating a significant difference between magnitudes ($F(1.5,84.12) = 6.91$, $p = 0.004$). Pairwise comparisons using the Bonferroni correction showed significant differences between the small magnitude and medium magnitude ($p = 0.007$) and the small magnitude and large magnitude ($p = 0.03$). No significant difference was found between the medium and large magnitudes.

Pearson's correlation indicated significant relations between the AA-F values and the small ($r = 0.30$, $p = 0.03$), medium ($r = 0.45$, $p < 0.001$), and large magnitude ($r = 0.42$, $p = 0.001$). Similarly, significant relations were observed between the FCQ and AUC ($r = -0.48$ to -0.30, $p < 0.05$). The three magnitudes of the FCQ were significantly correlated with one another ($r = 0.47$ to 0.8, $p < 0.05$).

Subjective hunger significantly correlated with discounting values of the adjusting amount procedure ($r = 0.47$, $p < 0.001$) and the medium ($r = 0.47$, $p < 0.001$) and large ($r = 0.34$, $p = 0.01$) magnitudes of the FCQ. Time since last meal or snack did not show a significant correlation. No significant relations among weight-status, substance use, alcohol use, and demographic variables were observed across the food delay discounting tasks.

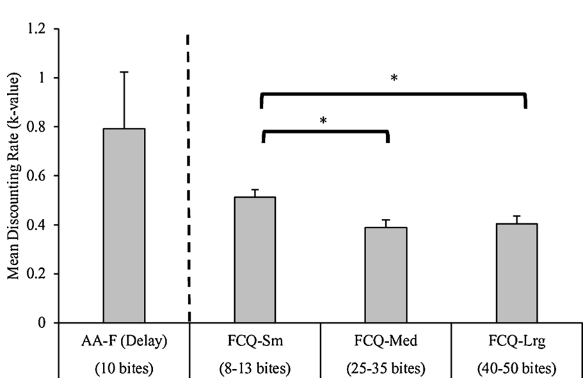

Fig. 4. Mean discounting values the delay adjusting amount procedure and the small, medium, and large magnitudes of the Food Choice Questionnaire. A significant difference was observed between the small, medium, and large magnitudes. Error bars represent 1 SEM. *$p < .05$.

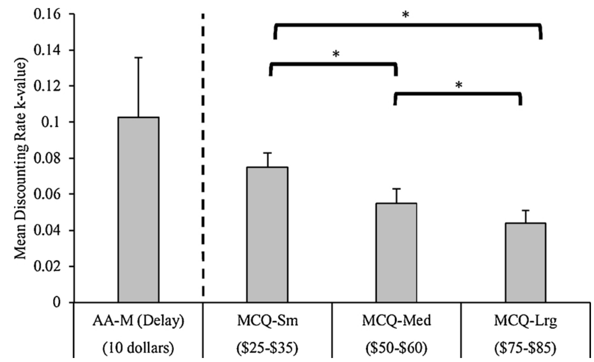

Fig. 5. Mean discounting values the delay adjusting amount procedure and the small, medium, and large magnitudes of the Monetary Choice Questionnaire. A significant difference was observed between the small, medium, and large magnitudes. Error bars represent 1 SEM. *$p < .05$.

3.3.4. MCQ and AA-M for delay discounting

Fig. 5 displays the mean discounting values of the computerized monetary discounting task and across the three magnitudes of the MCQ.

Due to a violation of sphericity ($\chi^2(2) = 10.14$, $p = 0.006$), Huynh-Feldt corrected tests were used. A repeated-measures ANOVA revealed significant differences between the magnitudes ($F(1.73,86.72) = 17.69$, $p < 0.001$). Pairwise comparisons with the Bonferroni correction revealed significant differences between the small magnitude and the medium magnitude ($p = 0.001$), and the small and large magnitudes ($p < 0.001$), and the medium and large magnitudes ($p = 0.02$). Pearson correlations indicated significant, positive relations between the AA-M and the small, ($r = 0.69$, $p < 0.001$), medium ($r = 0.72$, $p < 0.001$), and large ($r = 0.62$, $p < 0.001$) magnitudes of the MCQ. In addition, significant, negative correlations were found between AUC and the small ($r = -0.69$, $p < 0.001$), medium ($r = -0.70$, $p < 0.001$), and large ($r = -0.57$, $p = 0.001$) magnitudes. No significant relations were observed between weight-status, substance use, alcohol use, demographic, or consumption variables with money delay discounting.

3.3.5. Correlations between probability and delay discounting

The medium magnitude h value of the PFCQ and the k value of the delay adjusting amount procedure for food correlated ($r = 0.29$, $p = 0.03$). The AUC value from the AA-F for delay discounting showed a significant, negative association with the h value ($r = -0.27$, $p = 0.04$) and a significant, positive association with the AUC value ($r = 0.34$, $p = 0.009$) of the AA-F probability discounting task. For probability and delay discounting of monetary outcomes, the high magnitude k value of the MCQ and medium magnitude h value of the PMCQ showed a significant correlation ($r = 0.27$, $p = 0.05$), and the medium magnitude k value of the MCQ and AUC from the adjusting amount probability task showed a significant, negative association ($r = -0.29$, $p = 0.04$). In addition, both delay and probability adjusting amount procedure AUCs showed a positive relation ($r = 0.3$, $p = 0.04$).

4. Discussion

The current study developed and established a novel probability discounting measure, the Probabilistic Food Choice Questionnaire (PFCQ), and investigated its associations to demographic and health variables. Development of the measure was patterned after properties of three established discounting measures: the Probabilistic Monetary

Choice Questionnaire (PMCQ; Madden et al., 2009), the Monetary Choice Questionnaire (MCQ; Kirby et al., 1999), and the Food Choice Questionnaire (FCQ; Hendrickson et al., 2015). The discounting values generated from the PFCQ strongly correlated with those from the well-established adjusting amount procedure for food (AA-F; Rasmussen et al., 2010), with correlations ranging from 0.66 to 0.75. In addition, the PFCQ showed a high consistency in responding (98–99%) that is similar to the FCQ. The relatively brief nature of the administration and scoring of the PFCQ may offer an easy-to-administer alternative to assessing food probability discounting.

As a measure of money probability discounting, the PMCQ showed high consistency in responding (99%). Two magnitudes of the PMCQ–$20 vs. $80 and $40 vs. $100, but not $40 vs. $60– also revealed significant correlations with the AA-M probability discounting task (Richards et al., 1999). It is noteworthy that the magnitudes of the PMCQ that correlate more strongly with the AA-M probability discounting task have larger differences between the smaller and larger values. It may be that relatively more extreme differences between the smaller, for sure amount relative to the larger, uncertain amount are necessary to demonstrate significant relations between different probability discounting tasks. In addition, unlike the other choice questionnaires, the reward amounts within each magnitude of the PMCQ do not change from item to item—only the probability of receiving reward. It may be the lack of variability in the reward amounts that contribute to inconsistent associations with the AA-M. However, more research on altering the rewards amount on the PMCQ is needed.

We replicated many aspects of the delay discounting data. First, the FCQ showed a significant magnitude effect (i.e., steeper discounting for small compared to larger magnitude rewards), which replicates previous research (Hendrickson et al., 2015). There also were significant associations between all magnitudes of the FCQ and AA-F (delay discounting), suggesting relative discount rates may correspond across task methodologies. Similarly, a magnitude effect, which smaller magnitudes yielding the largest discounting rates, was observed with the MCQ. Values from the MCQ also correlated with those from the AA-M for delay discounting. All of these findings have been previously reported in recent studies (e.g., Amlung and MacKillop, 2011; Hendrickson et al., 2015).

In addition, a reversed magnitude effect (an increase in discounting as the size of the larger, uncertain reward increased) was found for food probability discounting, but not monetary probability discounting. The lack of magnitude effects across using the PMCQ is consistent with previous research (Madden et al., 2009). Some PD studies have shown a reverse magnitude effect with increased discounting associated with an increase in the larger, less certain outcome (e.g., Green et al., 1999; Myerson et al., 2011; Myerson et al., 2003; Yi et al., 2007) while others have not (e.g., Greenhow et al., 2015; Madden et al., 2009). This inconsistency may be due to the differences in rewards amounts. Previous research has demonstrated magnitude effects between amounts ranging from thousands of dollars (Holt et al., 2003; Myerson et al., 2011; Yi et al., 2007) to millions of dollars (Myerson et al., 2011); however, smaller amounts (e.g., $20–$100; Greenhow et al., 2015; Madden et al., 2009) appear to not be as robust. The PMCQ utilizes smaller amounts relative to previous research (e.g., Holt et al., 2003), which may also limit the ability to detect significant differences in probability discounting rates between magnitudes (Madden et al., 2009). Similarly, it may be the non-significant differences between the small and medium magnitudes and the medium and large magnitudes of the PFCQ is due to lack of substantial differences between the amounts to produce a magnitude effect. Whereas the difference between the small and large magnitude is substantial to detect an effect. More research is needed in this area.

Previous research suggests that probability and delay discounting are two separate, distinct processes (Green et al., 1999; Jarmolowicz et al., 2012; Madden et al., 2009; Reynolds et al., 2004). While the current study was consistent with previous findings for the most part, there were some, albeit small, associations between probability and delay discounting for food and for monetary outcomes. The h value of the medium magnitude (26–36 bites) of the PFCQ and k value from the delay AA-F procedure showed a positive association. In addition, the AUC from the delay AA-F showed an association with the h value and AUC of the probability AA-F. For monetary outcomes, the k value from the high magnitude ($75–$85) of the MCQ demonstrated a significant relation with the h value of the medium magnitude ($40 vs. $100) of the PMCQ. The medium magnitude ($50–$60) k value of the MCQ showed an association with the AUC value of the AA-M probability procedure. In addition, both probability and delay AUC values from the AA-M were significantly related. Given the small effects found and inconsistent associations between different measures of delay and probability discounting within the current the study, it is likely they represent two distinct processes. However, the examination of the association between the two processes as a function of reward type and amount may be an avenue for future research.

Another important and novel contribution of this study was the inclusion of amount sensitivity and random responding questions to the measures. Preference for the larger amount is often assumed (rather than measured) in discounting studies, and this can lead to an artificially-inflated discounting rate (Paglieri et al., 2015). For sensitivity to amount choices for uncertain food outcomes (PFCQ), 3–10% participants selected the smaller, certain amount relative to a larger certain amount. None of the participants chose the smaller amount for money on the PMCQ. In examining delay discounting (FCQ), 12–16% of individuals selected the smaller, immediate food choices over the large, immediate food choices; for the MCQ, 10–18% selected the smaller over larger. The selection of the smaller amount relative to the large amount of food is not surprising, as some individuals (e.g., those who diet) try to exhibit self-control by choosing a smaller amount of food, however, the percent of participants choosing the smaller monetary amount on the MCQ was surprising. One possibility is that the wording of the amount sensitivity questions (e.g., “4 bites now or 13 bites in 0 h”; “$11 now or $35 in 0 days”) on the FCQ and MCQ resulted in confusion among some participants. Approximately five participants reported “being confused” about the 0-h delayed outcome, (e.g., they reported believing they would not receive the reward, when it in fact the 0-hour indicated it was immediately available). However, analyses conducted with and without individuals who selected the smaller, certain or immediate outcome instead of the larger, certain or immediate outcome did not alter the results of analyses. Nonetheless, more research is needed to more carefully examine amount sensitivity, and phrasing of these questions, in discounting studies.

For the random questioning questions on the probability choice questionnaires, a small number of individuals (2% on both the PFCQ and PMCQ) selected the larger, unavailable food or monetary reward (i.e., 0% chance of receiving). This suggests that a relatively limited number of individuals did not attend to the probability of receiving the rewards, whereas most preferred a smaller, certain amount relative to larger, unavailable amount. Neither of the delay choice questionnaires contained random responding questions.

The presentation of probability and delay discounting questions were different amongst the choice questionnaires and the adjusting amount procedures. The choice questionnaires presented probability and delay discounting questions on separate forms whereas the adjusting amount procedure had the questions interspersed with one another. This difference in presentation could possibly affect an individual’s pattern of responding; however, correlations between all magnitudes of the choice questionnaires and the adjusting amount procedure were still strong.

Both probability and delay discounting have been linked to numerous health outcomes such as gambling (Andrade and Petry, 2012; Holt et al., 2003; Madden et al., 2009), cigarette smoking (Bickel et al., 1999; Friedel et al., 2014; Richards et al., 1999; Yi et al., 2007, 2016), illicit substances (Kirby et al., 1999), and obesity (Bickel et al., 2014;

Hendrickson and Rasmussen, 2013; Hendrickson et al., 2015; Jarmolowicz et al., 2014; Rasmussen et al., 2010). While this study was focused on validating discounting measures more than linking discounting to health-related measures, we found no consistent associations between health variables and measures of delay and probability discounting. This is likely because the base rate for these problems in this sample was lower than national averages. For example, only 30% of our sample was overweight and 14% were obese, which is much lower than the combined national average of 68.5% (Ogden et al., 2014). It should also be noted that 41% of this sample screened positive for heavy drinking in the past year and 12% were current smokers, which compares to national averages of 44% and 15% of college students who report binge drinking and smoking, respectively (e.g., Centers for Disease Control and Prevention, 2016; Wechsler et al., 1995). Testing these discounting tasks with a more representative sample, for example, crowdsourcing with MTurk (e.g., Bickel et al., 2014), using a community sample, or perhaps comparing discounting in different populations may lead to different findings. If future research with the PFCQ in clinical populations demonstrates significant relations with weight, eating patterns, substance use, and other health-related variables, this could provide helpful information on underlying mechanisms that contribute to the development and maintenance of health difficulties. In addition, this could provide clinicians with specific targets for treatment. Further, the measure could be used to understand probability discounting patterns in populations where certainty of food is compromised (i.e., food insecure individuals). Interestingly, these individuals are more at risk for obesity in the United States (Kaur et al., 2015; Martin and Ferris, 2007).

In sum, the newly developed PFCQ demonstrated strong, significant positive correlations with previously established probability discounting tasks, offering a quicker alternative assessment tool for food probability discounting. The PFCQ was not assessed for test-retest reliability across two or more time points in this study and would be a next step for further validation of the measure. Indeed, the FCQ and AA-F for food delay and probability discounting has been tested across two time points within 1–2 weeks and has shown strong reliability (Hendrickson and Rasmussen, 2013, 2016). In addition, probability and delay discounting for hypothetical or potentially real monetary outcomes have shown strong test-retest reliability over three months to one year using other methodologies (Kirby, 2009; Odum, 2011; Ohmura et al., 2006). Future studies then should examine the reliability of PFCQ across multiple time points with varying time intervals between them.

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