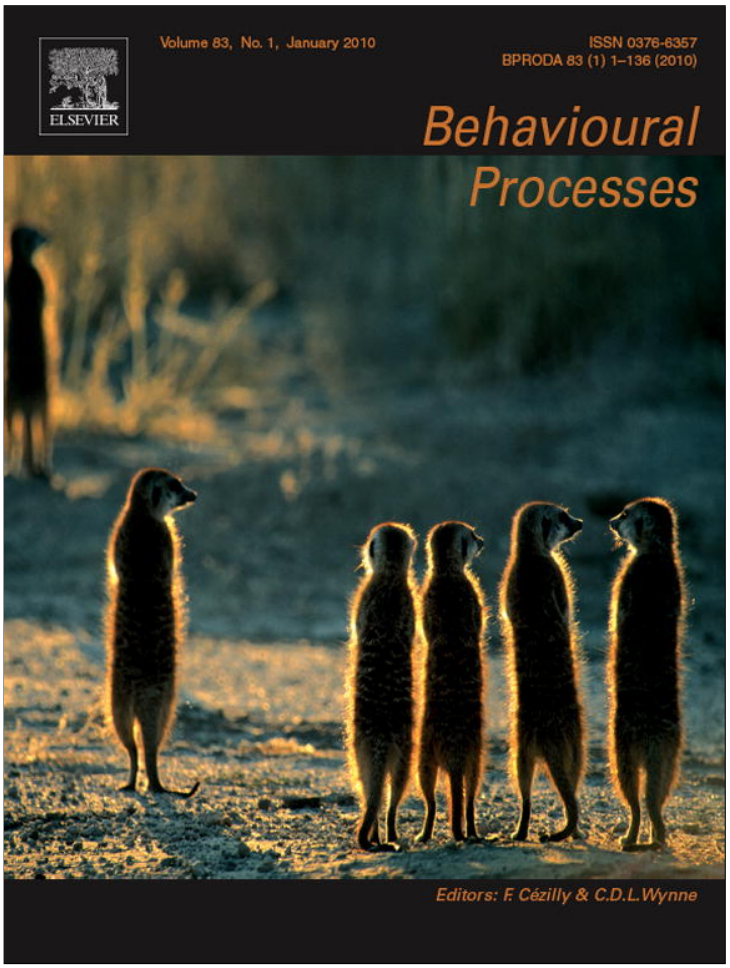

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Percent body fat is related to delay and probability discounting for food in humans

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ABSTRACT

This study describes delay and probability discounting patterns for hypothetical food and money in relation to percent body fat (PBF). Sixty university students completed four computerized discounting tasks in which they were asked to make a series of hypothetical decisions between (a) 10 dollars after one of several different delays (1, 2, 30, 180, and 365 days) or a smaller amount of money available immediately; (b) 10 bites of food after one of several delays (1, 2, 5, 10, and 20 h) or a smaller number of bites available immediately; (c) $10 at one of several probabilities (0.9, 0.75, 0.5, 0.25, 0.1) or a smaller amount of money to be received for sure; and (d) 10 bites of food at one of several probabilities (0.9, 0.75, 0.5, 0.25, 0.1) or a smaller number of bites to be received for sure. Median indifference points for all participants across each task were well described using the hyperbolic discounting function. Results suggest that percent body fat predicted discounting for hypothetical food, but not money, using regression analyses with the entire sample and when comparing individuals in the high and low quartiles for PBF. None of the other dietary variables (body mass index, subjective hunger, and time since last meal or snack) were related to discounting patterns. This suggests that individuals with high PBF may exhibit heightened sensitivities to delay and probability when making decisions about food.

1. Introduction

1.1. Delay discounting

Delay discounting (DD) refers to the degree to which delay to an outcome reduces its value. DD corresponds to the behavioral definition of impulsiveness, which is the tendency to choose small, relatively immediate rewards over larger, more delayed rewards (Ainslie, 1975; Rachlin, 1995; Rachlin et al., 1991). In research concerning discounting-related choice patterns in humans, researchers pose a series of forced-choice options to participants in which they choose between a relatively small reward (e.g., $10) available immediately and a larger delayed reward (e.g., $100 in 1 day). Over the course of the choices, the smaller sooner amount is adjusted incrementally to identify the point at which the individual "switches" from choosing the larger, delayed amount to choosing the smaller, sooner amount. This value, termed the "indifference point" represents the current subjective value of the larger reward. The series of choices is presented repeatedly across several different delay periods (e.g., one week, one month, six months), yielding indifference point values that typically decrease as a function of the delays (larger delays yield smaller indifference point values). The pattern of these indifference point values can be described using a hyperbolic discounting function:

$$V = \frac{A}{1 + kD} \tag{1}$$

In this equation, V represents the indifference point (or subjective value) of the delayed reward, A is the amount of the delayed reward, D is the delay of the reward, and k represents a free parameter that quantifies the rate of decay of the reward value as delay increases, or the relative degree of discounting (i.e., higher k values represent higher sensitivity to delay, or greater impulsivity).

1.2. Probability discounting

Probability discounting (PD) refers to the degree to which the value of a reward decreases as the odds against receiving it increase (Rachlin et al., 1991). The probability discounting task is similar to that used in delay discounting studies, except that an individual makes decisions between a relatively small reward amount (e.g., $10 for sure) and a larger, but less probable reward amount (e.g., 25% chance at $100). In the task, the smaller certain amount

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is adjusted to determine indifference point values for the larger amount across several probabilities and the patterns of these indifference point values can be characterized with a hyperbolic discounting function:

$$V = \frac{A}{1 + hO} \tag{2}$$

Here V represents the subjective value (indifference point) of a probabilistic reward, A represents the amount of the larger probabilistic reward, O represents the odds against receiving the larger reward $[(1/p) - 1]$, and p represents the probability of receiving the large outcome. The free parameter h indexes the rate of discounting in which higher values represent a preference for more certain outcomes over less certain ones. Probability discounting appears to represent impulsive behavior in a manner similar to delay discounting (e.g., Green et al., 1999), but may also represent more of an index of risk (Green et al., 1999; Green and Myerson, 2004; Holt et al., 2003) since a choice is being made between two outcomes that differ with regard to risk of not receiving them, instead of simply delaying a reinforcer.

1.3. Discounting and health problem behaviors

The delay discounting task has been used to address various socially-relevant health problem behaviors (see reviews by Critchfield and Kollins, 2001; Perry and Carroll, 2008; Reynolds, 2006). A large literature draws important connections between substance abuse, which has conceptual ties to impulse control problems, and choice patterns using discounting tasks. For example, discounting research consistently reports that heavy and problem drinkers (Vuchinich and Simpson, 1998), alcoholics (Odum and Rainaud, 2003; Petry, 2001), cigarette smokers (Bickel et al., 1999; Odum et al., 2002), and heroin addicts (Kirby et al., 1999; Madden et al., 1999, 1997) discount the value of delayed outcomes more than non-using comparison groups, suggesting that impulsive choice patterns are associated with a variety of substance abuse problems.

1.4. Discounting and food

With humans, the vast majority of discounting research has been centered on choices with regard to money (see reviews Critchfield and Kollins, 2001; Perry and Carroll, 2008; Reynolds, 2006). Recently, researchers have begun applying discounting to answer questions about food-related outcomes in humans. The hyperbolic discounting function nicely describes and quantifies hypothetical and real food choices in humans (Epstein et al., 2009; Estle et al., 2007; Odum et al., 2006; Odum and Rainaud, 2003) and real food choices in non-humans (Chelonis and Logue, 1997; Green et al., 2004; Mazur, 2000, 2007; Mitchell and Rosenthal, 2003; Ostaszewski et al., 2003; Perry et al., 2007; Saeki et al., 2002). Some of the human studies on food discounting have compared food discounting to other hypothetical outcomes and found that humans tend to discount the value of delayed hypothetical food rewards more steeply than, for example, hypothetical monetary rewards (Odum et al., 2006; Odum and Rainaud, 2003) and other secondary rewards (Charlton and Fantino, 2008), a phenomenon referred to as the domain effect. It has been suggested that because food is a primary reinforcer, it may be discounted more steeply than generalized or conditioned secondary reinforcers. However, when probability discounting is considered, food and money appear to be discounted similarly (Estle et al., 2007), though there are very few studies published on probabilistic discounting with food.

1.5. Discounting and obesity

Approximately 30–40% of Americans are overweight and more than 20–30% are obese (Kohn and Booth, 2003; Sturm, 2003) and this prevalence has increased in the last three decades (Centers for Disease Control, 2006). A variety of environmental factors that have changed over the past 30 years are associated with this increase in obesity. Consider, for example, the increased prevalence of fast-food restaurants in recent decades which allows quick access to high-calorie, inexpensive meals (Powell et al., 2007). These food alternatives may compete with delayed, possibly healthier meals made at home. Ready access to inexpensive, high-calorie foods and beverages increases the chances of consuming unhealthy (but palatable) food alternatives (e.g., cheeseburgers) over healthier food alternatives (Burdette and Whitaker, 2004; Proctor et al., 2003). Indeed, the increased prevalence of obesity is linked to increased prevalence and patronage of fast-food restaurants (Powell et al., 2007).

One key to understanding the factors that make food more reinforcing for obese individuals may have to do with understanding choices related to the environment. For example, an obese individual may be especially sensitive to delays in outcomes (i.e., may be more likely to make impulsive choices). Individuals who have higher body mass indices, for example, perform more impulsively on the Iowa Gambling Task than those with lower body mass indices (Davis et al., 2004; Pignatti et al., 2006). Moreover, a vast literature describing impulsivity in obese individuals comes from self-report data (e.g., Chalmers et al., 1990; de Zwaan et al., 1994; Nasser et al., 2004) and these studies generally suggest that obese individuals endorse more impulsive statements than individuals who are not obese. Self-report measures of impulsivity are informative, but are vulnerable to various response biases and do not provide opportunities for manipulating environmental factors that may influence impulsive food choices. An understanding of the factors that influence impulsive decision-making is fundamental to obesity treatment and prevention efforts.

Weller et al. (2008) recently reported discounting patterns in relation to hypothetical money among obese and non-obese participants. They found that obese women had higher rates of discounting (i.e., were more impulsive) than were healthy-weight women, suggesting that impulsive decisions are associated with obesity. This effect was specific to women, as no discounting differences in obese and healthy-weight men were found. No research to date has examined food-related discounting decisions in relation to health-related measures to determine whether impulsivity is a general pattern specific to many types of outcomes, or whether there is something unique about food that is associated with steeper discounting. However, such efforts are important in light of the aforementioned research that discounting rates for consumable outcomes (e.g., food) often are different than those for monetary outcomes. Moreover, numerous discounting studies have found stimulus-specific discounting patterns in individuals with experiences with those outcomes—smokers discount cigarettes more than non-smokers (Field et al., 2006), heroin addicts discount heroin-related outcomes more than non-addicts (Madden et al., 1999), and consumers of erotica discount erotic stimuli more than non-consumers of erotica (Lawyer, 2008). Therefore, a clearer understanding of food-related decisions in relation to weight-related health factors may provide important information about the behavioral processes that underlie problematic dietary decisions.

This study attempted to extend the growing discounting literature by (1) describing food- and money-related decisions using delay and probability discounting procedures and analyses, and (2) relating those data to diet-associated factors.

2. Materials and method

2.1. Participants

Sixty participants ($n = 43$ female) were recruited from undergraduate psychology courses at Idaho State University and received course credit for their participation in the study. The average age of the participants was 23.5 (SD = 6.4) years old; 90.0% ($n = 54$) reported European-American ethnicity. Participants were not asked to refrain from eating or drinking prior to the experimental session.

2.2. Discounting tasks

Discounting choices were delivered via a PC-compatible computer using a modified version of an established discounting program (see Richards et al., 1999 for details) used in some discounting studies (e.g., Lawyer, 2008). Questions for the delay and probability discounting task were intermixed and presented in a pseudorandom fashion within the food discounting task and within the money discounting task. The order of the food discounting task and the money discounting task was counterbalanced across participants.

2.2.1. Food discounting

Prior to the discounting tasks, participants were presented with a 1/2-in. cube that represented a standard bite and a research assistant read the following script:

> In the task that follows, you will have the opportunity to choose between food amounts after different delays or with 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 would have to choose from would be those given in the question. The test consists of about 110 questions, such as the following: (a) would you rather eat 10 bites of your favorite food available in 1 h, or 2 bites available in 5 h, or (b) would you rather eat 5 bites of food that is certain or 10 bites of food with a 25% chance? You will not receive any of the rewards that you choose, but we want you to make your decisions as though you were really going to get the rewards you choose.

In the delay-discounting task for food, participants responded to a series of choices between a relatively small number of standardized bites (e.g., 2 bites) "right now" and 10 bites of food after each of five delays (1, 2, 5, 10, and 20 h). After the participant chose one of the options via mouse click, the program would ask "Are you sure?" and a click on the "Yes" response would advance the participant to the next question. A click on "No" would re-present the question. On subsequent questions, the smaller amount was increased or decreased (±0.5 bites) until an indifference point was determined for each delay period.

In the probability discounting task for food, participants responded to a series of choices between a small number of standardized bites (e.g., 2 bites) "for sure" and 10 bites of food after each of five probabilities (0.9, 0.75, 0.5, 0.25, and 0.10). On subsequent questions, the smaller "for sure" amount was increased or decreased (±0.5 bites) until an indifference point was determined for each of the five probabilities.

2.2.2. Money discounting

Delay and probability discounting for money was assessed using the same computerized procedure used in the food discounting tasks except that "bites of food" was replaced with dollar amounts of money. No cube was presented before the money task. The large delayed outcome was $10 and indifference point values were established for five different delays (1, 2, 30, 180, and 365 days).

Prior to the money discounting task, a research assistant read the following script:

> In the task that follows, you will have the opportunity to choose between different amounts of money available after different delays or with different probabilities. The test consists of about 110 questions, such as the following: (a) Would you rather have $10 in 30 days or $2 at the end of the session, or (b) would you rather have $5 for sure at the end of the session or $10 with a 25% chance? You will not receive any of the rewards that you choose, but we want you to make your decisions as though you were really going to get the rewards you choose.

2.3. Physical measurements

A *Tanita 2204 Body Fat Scale* was used to measure percent body fat (PBF) and weight. The scale measured PBF using bioelectrical impedence. Participants' height was measured in centimeters using a standard tape measure.

2.4. Self-report measures

Participants provided basic demographic information (age, gender, religious affiliation, ethnicity, family annual income) and information regarding several health indices, including birth weight, exercise practices, cigarette usage, drug and alcohol usage, and current dieting practices. Participants also indicated on a scale of 0–100 (0 = not hungry at all, 100 = very hungry) self-reported subjective hunger level. They were also asked how many hours it had been since their last meal and last snack.

2.5. Procedure

Each participant was tested individually by an experimenter in an office-sized laboratory. After providing informed consent for participation, the experimenter measured participant weight, height, and PBF. Participants were positioned backward on the scale so they could not read their weights or body fat data. Half the participants then completed the self-report measures, followed by the discounting tasks; half completed the measures and discounting tasks before height, weight and percent body fat were measured. Body mass index (BMI) was calculated as the participant's weight (kg)/height (m)^2.

We also screened for individuals with problem drinking patterns in the sample using items from the Alcohol Use Disorders Identification Test (Saunders et al., 1993) as problem drinkers have been shown to have steeper rates of discounting. One problem drinker was found in the sample and data were analysed with and without this subject. Because the results were unaffected by the inclusion of this participant's data, we included him/her in the analyses.

3. Analysis

Data were analysed using SPSS 14.0 statistical software. Individual and group (median) indifference point data were fit to Eq. (1) (for delay discounting) and Eq. (2) (for probability discounting) using non-linear regression. Two methods were used to estimate rate of discounting. The k and h parameters derived from Eqs. (1) and (2) provided one measure of discounting rate, which is tied to the hyperbolic discounting function. (Data were also fit to the exponential model of discounting, but the hyperbolic function provided a better fit of the data.) A second measure, area under the curve (AUC) (Myerson et al., 2001), was used also to provide an atheoretical measure of discounting rate that is more appropriate

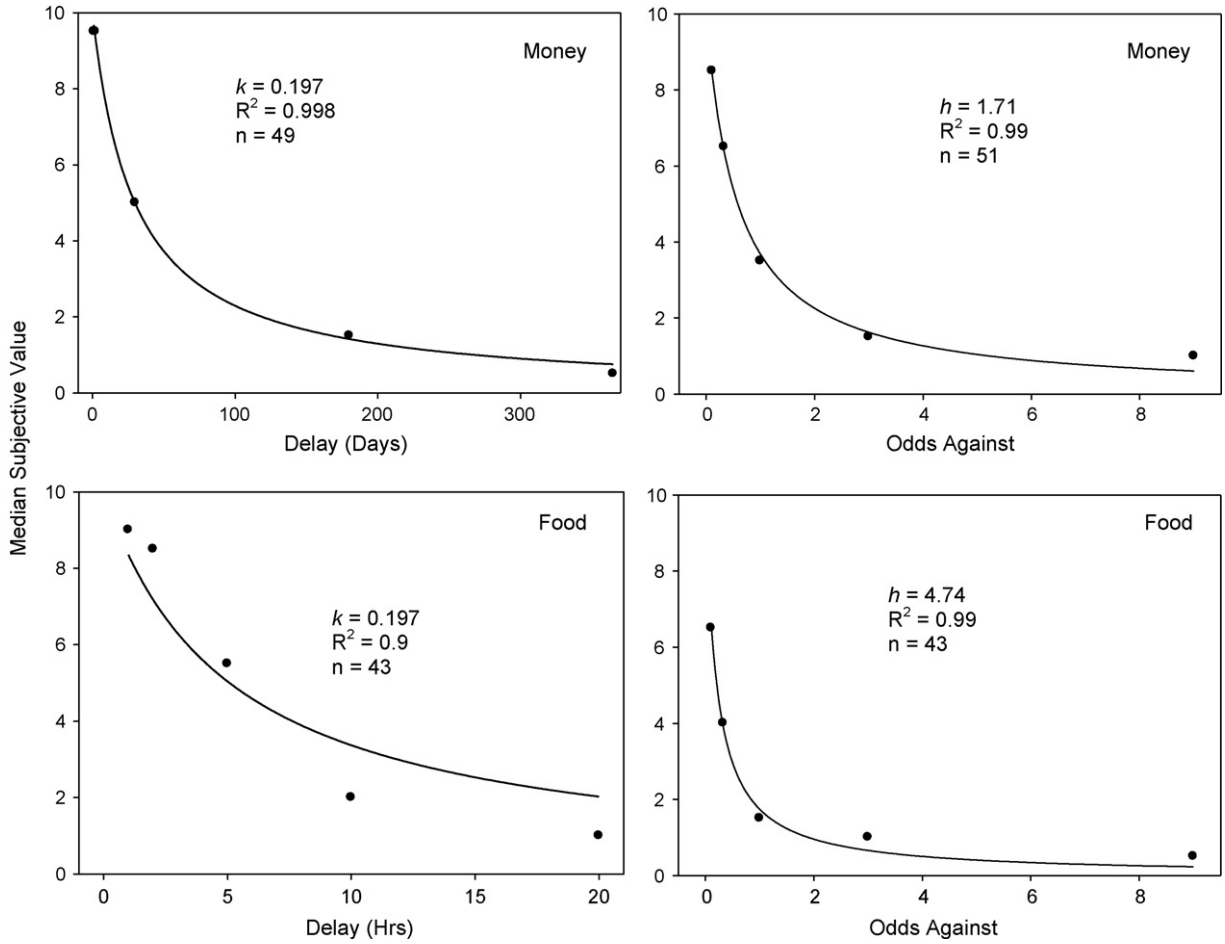

Fig. 1. Median indifference values regarding delay and probability money (upper two figures) and for food (lower two figures). Fit lines represent best fit of hyperbolic discounting function. In some cases two data points overlapped at the very short delays.

for parametric analyses than are *k* and *h* parameters, since outliers in these parameters may generate skewed distributions. The lower the AUC, the more the curve approximates the axes, and therefore, the steeper the discounting.

To reduce error associated with careless or random responding on the discounting tasks, we used Johnson and Bickel's (2008) algorithm for defining non-systematic data for individual participants. Specifically, if any indifference point was 20% greater than the preceding indifference point, or if the last indifference point was not less than the first indifference point by at least 10% of value of the largest reward value, that individual's data were removed from analysis.

Data were analysed in two ways. First, groups representing extremes (upper and lower quartiles) within each dietary variable were compared in terms of discounting rate (AUC). Second, the relationships between the dietary variables and discount rates across the behavioral tasks were established using the entire sample by way of a series of regression analyses.

4. Results

4.1. Discounting for food and money

Although there were relative differences in the frequency of non-systematic response patterns in the food versus money tasks, two χ^2 analyses revealed no statistically significant commodity-based difference in the frequency of non-systematic response patterns when comparing delay discounting for money ($n = 11$) and delay discounting for food ($n = 17$; $\chi^2 = 0.84$; $p = \text{ns}$) and when comparing probability discounting for money ($n = 9$) and probability discounting for food ($n = 17$; $\chi^2 = 1.57$; $p = \text{ns}$). For purposes of consistency, only data for systematic responders in each task are reported in relevant figures.

Fig. 1 shows delay (left) and probability (right) discounting curves for money (top) and food (bottom) for systematic responders within each task. The hyperbolic discounting function provided a good fit to group median data across all four discounting tasks, as indicated by the R^2 values (all values ≥ 0.90) in Fig. 1. In all four panels, the value of food or money decreased with delay or odds against receiving the outcome. When data from all 60 participants were included, the outcome did not change.

A comparison of area under the curve estimates across gender found that women had significantly lower AUCs on the delay and probability food tasks (Table 1) than men. This outcome was similar when all participants (including non-systematic responders) were included in the analysis. This suggests that women overall made more impulsive and risk-averse choices for food than men.

4.2. Diet factors associated with food discounting

For technical reasons, percent body fat data for seven participants (five female, two male) were not obtained. Therefore, these participants were excluded from all subsequent analyses. Descriptive data for the rest of the sample regarding the dietary variables are reported in Table 2, which shows that female participants had significantly higher PBF values than males. There were no gender

Table 1
Comparison of mean (SEM) area under the curve (AUC) estimates across discounting tasks and gender.

Discounting measures	All	Men	Women	*t*(df)	*p*
Delay money	0.33 (0.03)	0.37 (0.04)	0.32 (0.04)	0.69 (41)	ns
Probability money	0.23 (0.02)	0.26 (0.02)	0.22 (0.02)	1.08 (43)	ns
Delay food	0.30 (0.02)	0.37 (0.04)	0.27 (0.03)	2.11 (35)	0.04
Probability food	0.17 (0.02)	0.23 (0.04)	0.14 (0.02)	2.18 (34)	0.04

Systematic responders within each task only.

Table 2
Means (SEM) for dietary variables across gender.

	Total	Male ($n = 15$)	Female ($n = 38$)	*p*
PBF	28.0 (1.4)	20.7 (1.8)	30.9 (1.5)	<0.01[a]
BMI	25.2 (0.7)	26.3 (1.0)	24.8 (1.0)	ns
Subjective hunger	31.8 (4.2)	38.9 (7.6)	29.0 (5.1)	ns
Hours since last meal	8.7 (1.4)	8.0 (2.3)	8.9 (1.8)	ns
Hours since last snack	3.2 (0.5)	2.6 (0.4)	3.4 (0.7)	ns

Note. PBF = percent body fat; BMI = body mass index.
[a] $t(51) = -3.34$.

differences regarding body mass index, subjective hunger, hours since last meal, or hours since last snack. Income, birth weight, and exercise practices were unrelated to any discounting pattern.

In order to assess whether PBF, body mass index, or current subjective hunger, time since last meal, and time since last snack were associated with discounting patterns for food or money, the area under the curve estimates were compared across participants at the lowest (bottom 25%) and highest (top 25%) quartiles within each variable (these groups were selected to maximize the distinction between groups). Descriptive data regarding dietary factors within these groups are reported in Table 3. It is worth noting that only two participants in the highest quartile for BMI did not meet standard criteria for obesity (a BMI ≥30), though the lowest score of 29.7 suggests little deviation from that categorical status.

Fig. 2 shows mean AUC values for participants in the lowest and highest quartiles for PBF. Individuals in the highest quartile for PBF had significantly steeper discounting for the delay ($t(16) = 2.20$, $p = 0.05$) and probability ($t(18) = 2.62$, $p = 0.02$) discounting tasks. Although the patterns for the money tasks were similar to those for food, there were no significant effects for PBF on delay ($p = 0.18$) or probability ($p = 0.15$) discounting for money. AUC comparisons across the upper and lower quartile groups among other dietary variables were not significant (p's > 0.05).

These results may offer one explanation for the gender effect reported in Table 1, since there were disproportionately more women than men ($\chi^2 = 10.56$, $p < 0.01$) in the highest quartile for body fat (100%; $n = 13$) than in the lowest quartile (42.9%; $n = 6$).

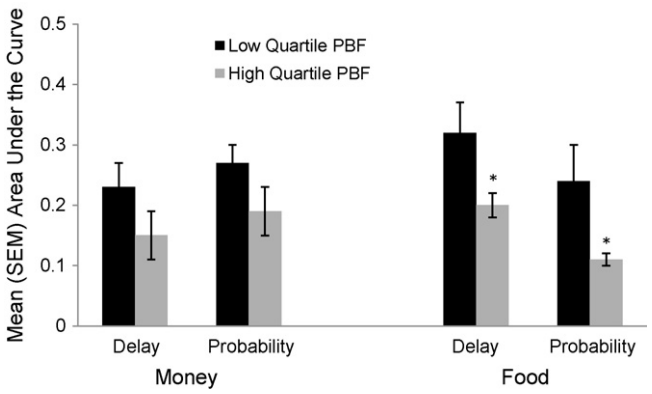

Fig. 2. Mean (±1SE) area under the curve estimates across tasks for participants in the low and high and quartiles for body fat percentage. $^{*}p < 0.05$.

There were no disproportional gender representations in the lowest and highest quartiles for BMI or subjective hunger.

It is also possible that smoking status contributed to the relationship between PBF and discounting. A smoker in this study was defined as endorsing "yes" to the question of "Do you smoke?"; the average smoker in this sample smoked 9.64 cigarettes per day. There were disproportionately more smokers in the highest quartile PBF group ($n = 4$; 30.8%) than in the lowest quartile group ($n = 0$; 0%)($\chi^2 = 5.06$, $p = 0.03$). However, smoking status is not a likely confound, as a comparison of AUC estimates between the relatively few smokers ($n = 7$) and non-smokers ($n = 46$) revealed no between-group differences (all $ps \geq 0.68$).

In order to better understand how gender and PBF were related to discounting, we compared AUC values for the discounting tasks using only females in the lowest and highest quartiles across all three dietary measures. All effects were the same, except for probability discounting for food, in which those with BMIs in the highest quartile discounted the value of probabilistic food at a higher rate (mean AUC = 0.12, SEM = 0.02) than did those with BMIs in the lowest quartile (mean AUC = 0.22, SEM = 0.04; $t(18) = 2.13$, $p = 0.05$).

The findings reported thus far suggest important differences in discounting rate when comparing individuals at two extremes (upper and lower quartiles) of a dietary variable. In order to determine whether the relationships between dietary variables (BMI, PBF, time since last meal, time since last snack, and subjective hunger) and discounting rate for food and money were similar when considering the full range of participants, a series of hierarchical linear regression analyses were conducted to establish the unique variability that the dietary variables contributed to discounting rate. Due to significant co-linearity between PBF and BMI ($r = 0.70$, $p < 0.001$) we conducted two hierarchical linear regressions with BMI and PBF using each AUC estimate with only systematic responders within each task. In the first regression, time since last meal, time since last snack, subjective hunger and PBF were entered in the first step and BMI was entered in the second step. In the second regression, time since last meal, time since last snack, subjective hunger were entered in the first step and PBF was entered in the second step.

Significant effects are shown in Table 4. Only PBF was uniquely associated with AUC for probability discounting for money (accounting for 22% of the variance), delay discounting for food (accounting for 11% of the variance) and probability discounting for food (accounting for 20% of the variance). When all participants (including non-systematic responders) were included, the effect remained for both food tasks, but not the probability money task. No dietary variables were significantly associated with AUC for money delay discounting.

5. Discussion

In this study, delay discounting and probability discounting patterns for food and money were characterized in humans and related to two variables associated with physical health (body mass index and percent body fat) and with variables associated with current hunger status (current subjective hunger and hours since last meal and snack). Consistent with a growing literature, choice patterns for

Table 3
Means (SEM) and ranges for dietary variables across upper and lower quartiles within each variable.

	Lower quartile			Upper quartile		
	n	Mean (SEM)	Range	*n*	Mean (SEM)	Range
BMI	13	19.80 (0.28)	17.8–21.3	13	32.26 (0.82)	29.7–39.7
PBF	14	16.94 (0.78)	11.5–20.7	13	44.53 (2.92)	38.8–48.6
Subjective hunger	15	0.0 (0.0)	0.0–0.0	13	76.38 (3.68)	55.0–100
Time since meal	14	0.81 (0.11)	0.0–2.0	13	23.46 (2.54)	17.0–48.0
Time since snack	16	0.51 (0.05)	0.0–1.0	13	8.28 (1.10)	4.0–15.0

Table 4
Significant[a] hierarchical regression coefficients for percent body fat in relation to area under the curve estimates across discounting tasks.

Task	*b* (SE)	β	*t*(df)	R^2 Δ	Significance
Probability money	−0.007 (0.002)	−0.649	−3.261 (5, 41)	0.22	<0.01
Delay food	−0.008 (0.004)	−0.527	−0.2176 (5, 32)	0.11	<0.05
Probability food	−0.007 (0.003)	−0.64	−2.786 (5, 32)	0.20	<0.01

[a] Regression coefficients for BMI, subjective hunger, time since last meal and time since last snack also were calculated, but were non-significant (all *ps* > 0.05).

money were well described by the hyperbolic discounting function (Green et al., 1994, 1997; Jikko and Okouchi, 2007; Kirby, 2006; Lagorio and Madden, 2005; Madden et al., 2003, 1999, 1997; Sugiwaka and Okouchi, 2004). In addition, our findings replicate other studies (Epstein et al., 2008; Estle et al., 2007; Odum et al., 2006; Odum and Rainaud, 2003) indicating that food-related decisions can be characterized using discounting procedures and described using the hyperbolic decay model. These data add to a growing literature demonstrating that the discounting paradigm is useful for studying decisions for both monetary and non-monetary (Charlton and Fantino, 2008; Lawyer, 2008) outcomes.

5.1. BMI, PBF, and discounting

Findings from this study indicate that percent body fat was a significant and consistent predictor of discounting patterns for food. When comparing individuals at the upper and lower quartiles for PBF in terms of discounting rate, high-PBF participants had steeper discounting curves than did low-PBF participants, but only for the food-related tasks. This suggests that individuals who have higher body fat percentages tend to make more impulsive food-related decisions than those with relatively lower body fat percentages and that high-PBF individuals may be more risk-averse (choose the more certain outcome) when it comes to food availability compared to lower-PBF individuals.

Gender also was related to PBF and steeper discounting for food. The majority of the high-PBF sample was female, which is not surprising, given that women generally have higher PBFs than men (e.g., see review by Power and Schulkin, 2008). Although high-PBF individuals still discounted more steeply than low-PBF when women only were analysed in the present study, it is difficult to make substantive statements regarding gender, as there were not enough males in the sample. However, the data reported suggest that for women, a higher percent body fat may be a predictor for steeper discounting patterns.

Interestingly, steeper discounting was not evident when we compared individuals in the highest and lowest quartiles for BMI, nor was BMI uniquely associated with discounting rates across the whole sample after controlling for PBF. Weller et al. (2008) reported differences in delay discounting for money that were related to BMI. Women (but not men) who met the criterion for an obese BMI showed steeper discounting for money than healthy-weight women. Our findings are similar in general with Weller's in that a measure of obesity in women predicted steeper discounting. Yet, our results also contrast somewhat with those reported by Weller et al. in that we did not find any relationship between BMI and discounting rate for delay money or any other task. Our findings in the DD-money task may differ from Weller et al.'s results due to some methodological differences in the studies. One, Weller et al. used monetary values that were much greater (up to $50,000) than we did ($10) in addition to using delays that were much longer (up to 3600 days) than ours (up to 365 days). Discounting rates vary as a function of the amount of the outcome (e.g., Johnson and Bickel, 2002) and Weller et al. found stronger differences in discounting when comparing discounting for larger amounts of money ($50,000) versus smaller ($1000) amounts. Future research should determine whether differences in these findings are due to study parameters.

Another explanation for the difference between our findings in the DD-money task and those of Weller et al. is that PBF, rather than BMI, may be an important factor in food- and money-related decision-making. BMI has been criticized by some (e.g., Garn et al., 1986) as a measure of obesity because it fails to account for lean muscle mass and is sensitive to standing height. Percent body fat may be a better measure of obesity because it accounts for these limitations. It is possible that in Weller et al.'s study, obese participants also had elevated body fat percentages, which may explain their findings; however, Weller's study did not report PBF.

5.2. Subjective hunger and discounting

Contrary to our expectations, there was no relationship between subjective hunger, hours since last meal or snack, and rates of discounting for food (or money). Some discounting studies suggest that higher deprivation levels influence discounting rates. For example, food deprivation (Ostaszewski et al., 2004) leads to steeper discounting of delayed food, nicotine deprivation leads to steeper discounting of nicotine-related outcomes (Field et al., 2006; Mitchell, 2004), and opiate deprivation leads to steeper discounting of heroin-related outcomes (Giordano et al., 2002).

We did not deprive participants of food as a way to increase subjective hunger, but used subjective indicators, which can be unreliable. Other studies suggest that inducing deprivation may create steeper discounting patterns. Kirk and Logue (1996), for example, found that humans who were given soup before an experimental session showed more self-control in choosing differing amounts of juice across different delays than those who were food deprived. Future studies might consider depriving human participants of food for standardized amounts of time to better examine how this factor affects money- or food-related choices. Indeed, such a study would represent an interesting test of Loewenstein's (1996) hypothesis that food deprivation should lead to increased impulsive choices for food-related, but not other, outcomes.

It is also possible that our failure to find an effect for subjective hunger is related to our discounting task. Some researchers (Reynolds & Schiffbauer, 2004) argue that question-based measures of discounting based on hypothetical outcomes, such as the measures used here, may not be as sensitive to moment-to-moment state factors as some recently-developed real-time measures of discounting (Reynolds and Schiffbauer, 2004) that have demonstrated sensitivity to transient "state" factors, such as alcohol intoxication (e.g., Reynolds et al., 2006). Some researchers have used real food-related outcomes in real-time discounting paradigms (e.g., Kirk and Logue, 1997) in humans, so future research might consider using real food outcomes to examine effects of food deprivation (or relations to BMI and PBF) in human participants.

5.3. General conclusions and future directions

The present study indicates that discounting patterns for relatively small amounts of food and money can be characterized and compared in individuals who have differing percent body fat values. This is important for future studies examining food-related decisions in terms of bites. Other researchers who examine food-related discounting have used amounts of hypothetical food that are larger than what is ingestible in a given sitting (e.g., numerous whole pizzas; see Estle et al., 2007; Odum et al., 2006). While decisions regarding these outcomes yielded meaningful discounting data across relatively large time spans (e.g., months or years), research concerning food decisions on shorter time scales (e.g., hours) with smaller amounts may help characterize short-term food decisions that better represent day-to-day diet decisions regarding an individual's food consumption in a single sitting.

Future research concerning food-related choices might consider examining discounting behavior in relation to different types of food outcomes. In the present study, we asked participants to visualize a 1/2-in. cube of their favorite food, but we did not query them regarding what food they imagined (e.g., "junk" food versus something healthy). Certainly, in the context of obesity, choice patterns for certain foods (e.g., high-fat junk food) may be more related to health outcomes than others (e.g., healthy foods). Therefore, food type may be an important part of the decision-making process when it comes to discounting, though it has not been examined in this context.

We were not able to compare food to money directly in the present study because the units (bites versus dollars) and temporal intervals used for the delays (hours versus days, respectively) were qualitatively different. Several studies, however, have found support for the domain effect (see Charlton and Fantino, 2008), in that people tend to devalue consumable rewards (e.g., food, drugs) at smaller delays than non-consumable rewards (e.g., money), even when the value of the consumable and monetary rewards are equated (e.g., Odum et al., 2006). This may be because money serves as a secondary reinforcer exchangeable for a variety of goods in a delayed period of time by contrast with outcomes such as food, which serve as primary (and perishable) reinforcers that are often consumed immediately (Forzano and Logue, 1994). It would be interesting to equate food and money using the smaller outcomes and smaller time-frames used in this study, such that they could be compared, since such findings may be relevant for understanding food versus money discounting in relation to weight-related health outcomes.

Finally, some recent research supports an inverse relationship between intelligence and discounting in middle-aged adult (deWit et al., 2007) and college populations (Shamosh et al., 2008). We did not include a measure of intelligence in the present study, so we were unable to control for this variable. Discounting researchers might consider controlling for intelligence in future human discounting studies to minimize variability that this factor may contribute.

References

Ainslie, G., 1975. Specious reward: a behavioral theory of impulsiveness and impulse control. Psychological Bulletin 82, 463–496.

Bickel, W.K., Odum, A.L., Madden, G.J., 1999. Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. Psychopharmacology 146, 447–454.

Burdette, H.L., Whitaker, R.C., 2004. Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. Preventive Medicine: An International Journal Devoted to Practice & Theory 38, 57–63.

Centers for Disease Control, 2006. State-specific prevalence of obesity among United States, 2005. Journal of the American Medical Association 16, 1959–1969.

Chalmers, D.K., Bowyer, C.A., Olenick, N.L., 1990. Problem drinking and obesity: a comparison in personality patterns and life-style. International Journal of the Addictions 25, 803–817.

Charlton, S.R., Fantino, E., 2008. Commodity specific rates of temporal discounting: does metabolic function underlie differences in rates of discounting? Behavioural Processes 77, 334–342.

Chelonis, J., Logue, A.W., 1997. Effects of reinforcer type on rats sensitivity to variation in reinforcer amount and delay. Behavioural Processes 39, 187–203.

Critchfield, T.S., Kollins, S.H., 2001. Temporal discounting: basic research and the analysis of socially important behavior. Journal of Applied Behavior Analysis 34, 101–122.

Davis, C., Levitan, R.D., Muglia, P., Bewell, C., Kennedy, J.L., 2004. Decision-making deficits and overeating: a risk model for obesity. Obesity Research 12, 929–935.

de Zwaan, M., Mitchell, J.E., Seim, H.C., Specker, S.M., 1994. Eating related and general psychopathology in obese females with binge eating disorder. International Journal of Eating Disorders 15, 43–52.

deWit, H., Flory, J.D., Acheson, A., McCloskey, M., Manuck, S.B., 2007. IQ and nonplanning impulsivity are independently associated with delay discounting in middle aged adults. Personality and Individual Differences 42, 111–121.

Epstein, L.H., Dearing, K.H., Temple, J.L., Cavanaugh, M.D., 2008. Food reinforcement and impulsivity in overweight children and their parents. Eating Behaviors 9, 319–327.

Estle, S.J., Green, L., Myerson, J., Holt, D., 2007. Discounting of monetary and directly consumable rewards. Psychological Science 18, 58–63.

Field, M., Santarcangelo, M., Sumnall, H., Goudie, A., Cole, J., 2006. Delay discounting and the behavioural economics of cigarette purchases in smokers: the effects of nicotine deprivation. Psychopharmacology 186, 255–263.

Forzano, L.B., Logue, A.W., 1994. Self control in humans: comparison of qualitatively different reinforcers. Learning and Motivation 25, 65–82.

Garn, S., Leonard, W., Hawthorne, V., 1986. Three limitations of the body mass index. American Journal of Clinical Nutrition 44, 996–997.

Giordano, L.A., Bickel, W.K., Loewenstein, G., Jacobs, E.A., Marsch, L., et al., 2002. Mild opioid deprivation increases the degree that opioid-dependent outpatients discount delayed heroin and money. Psychopharmacology 163, 174–182.

Green, L., Myerson, J., 2004. A discounting framework for choice with delayed and probabilistic rewards. Psychological Bulletin 130, 769–792.

Green, L., Fristoe, N., Myerson, J., 1994. Temporal discounting and preference reversals in choice between delayed outcomes. Psychonomic Bulletin & Review 1, 383–389.

Green, L., Myerson, J., McFadden, E., 1997. Rate of temporal discounting decreases with amount of reward. Memory & Cognition 25, 715–723.

Green, L., Myerson, J., Ostaszewski, P., 1999. Amount of reward has opposite effects on the discounting of delayed and probabilistic outcomes. Journal of Experimental Psychology: Learning, Memory, and Cognition 25, 418–427.

Green, L., Myerson, J., Holt, D.D., Slevin, J.R., Estle, S.J., 2004. Discounting of delayed food rewards in pigeons and rats: is there a magnitude effect? Journal of the Experimental Analysis of Behavior 81, 39–50.

Holt, D.D., Green, L., Myerson, J., 2003. Is discounting impulsive? Evidence from temporal and probability discounting in gambling and non-gambling college students. Behavioural Processes 64, 355–367.

Jikko, Y., Okouchi, H., 2007. Real and hypothetical rewards in probability discounting. Japanese Journal of Psychology 78, 269–276.

Johnson, M., Bickel, W., 2002. Within-subject comparison of real and hypothetical money rewards in delay discounting. Journal of the Experimental Analysis of Behavior 77, 129–146.

Johnson, M.W., Bickel, W.K., 2008. An algorithm for identifying nonsystematic delay-discounting data. Experimental and Clinical Psychopharmacology 16, 264–274.

Kirby, K.N., 2006. The present values of delayed rewards are approximately additive. Behavioural Processes 72, 273–282.

Kirby, K.N., Petry, N.M., Bickel, W.K., 1999. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. Journal of Experimental Psychology: General 128, 78–87.

Kirk, J.M., Logue, A.W., 1997. Effects of deprivation level on humans' self control for food reinforcers. Appetite 28, 215–226.

Kohn, M., Booth, M., 2003. The worldwide epidemic of obesity in adolescents. Adolescent Medicine 14, 1–9.

Lagorio, C.H., Madden, G.J., 2005. Delay discounting of real and hypothetical rewards III: steady-state assessments, forced-choice trials, and all real rewards. Behavioural Processes 69, 173–187.

Lawyer, S.R., 2008. Probability and delay discounting of erotic stimuli. Behavioural Processes 79, 36–42.
Loewenstein, G., 1996. Out of control: visceral influences on behavior. Organizational Behavior and Human Decision Processes 65, 272–292.
Madden, G.J., Petry, N.M., Badger, G.J., Bickel, W.K., 1997. Impulsive and self-control choices in opioid-dependent patients and non-drug-using control patients: drug and monetary rewards. Experimental and Clinical Psychopharmacology 5, 256–262.
Madden, G.J., Bickel, W.K., Jacobs, E.A., 1999. Discounting of delayed rewards in opioid-dependent outpatients: exponential or hyperbolic discounting functions? Experimental and Clinical Psychopharmacology 7, 284–293.
Madden, G.J., Begotka, A.M., Raiff, B.R., Kastern, L.L., 2003. Delay discounting of real and hypothetical rewards. Experimental and Clinical Psychopharmacology 11, 139–145.
Mazur, J.E., 2000. Tradeoffs among delay, rate, and amount of reinforcement. Behavioural Processes 49, 1–10.
Mazur, J.E., 2007. Rats' choices between one and two delayed reinforcers. Learning & Behavior 35, 169–176.
Mitchell, S.H., 2004. Effects of short-term nicotine deprivation on decision-making: delay, uncertainty and effort discounting. Nicotine & Tobacco Research 6, 819–828.
Mitchell, S., Rosenthal, A., 2003. Effects of multiple delayed rewards on delay discounting in an adjusting amount procedure. Behavioural Processes 64, 273–286.
Myerson, J., Green, L., Warusawitharana, M., 2001. Area under the curve as a measure of discounting. Journal of the Experimental Analysis of Behavior 76, 235–243.
Nasser, J.A., Gluck, M.E., Geliebter, A., 2004. Impulsivity and test meal intake in obese binge eating women. Appetite 43, 303–307.
Odum, A.L., Rainaud, C.P., 2003. Discounting of delayed hypothetical money, alcohol, and food. Behavioural Processes 64, 305–313.
Odum, A.L., Madden, G.J., Bickel, W.K., 2002. Discounting of delayed health gains and losses by current, never- and ex-smokers of cigarettes. Nicotine & Tobacco Research 4, 295–303.
Odum, A.L., Baumann, A.A.L., Rimington, D.D., 2006. Discounting of delayed hypothetical money and food: effects of amount. Behavioural Processes 73, 278–284.
Ostaszewski, P., Karzel, K., Bialaszek, W., 2004. Temporal discounting in RHA/Verh and RLA/Verh rats: adaptation to food deprivation. Polish Psychological Bulletin 35, 91–97.
Perry, J.L., Carroll, M.E., 2008. The role of impulsive behavior in drug abuse. Psychopharmacology 200, 1–26.
Perry, J.L., Nelson, S.E., Anderson, M.M., Morgan, A.D., Carroll, M.E., 2007. Impulsivity (delay discounting) for food and cocaine in male and female rats selectively bred for high and low saccharin intake. Pharmacology, Biochemistry and Behavior 86, 822–837.
Petry, N.M., 2001. Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. Psychopharmacology 154, 243–250.
Pignatti, R., Bertella, L., Albani, G., Mauro, A., Molinari, E., Semenza, C., 2006. Decision-making in obesity: a study using the Gambling Task. Eating and Weight Disorders 11, 126–132.
Powell, L.M., Chaloupka, F.J., Bao, Y., 2007. The availability of fast-food and full-service restaurants in the United States: associations with neighborhood characteristics. American Journal of Preventive Medicine 33, S240–s245.
Power, M.L., Schulkin, J., 2008. Sex differences in fat storage, fat metabolism, and the health risks from obesity: possible evolutionary origins. British Journal of Nutrition 99, 931–940.
Proctor, M.H., Moore, L.L., Gao, D., 2003. Television viewing and change in body fat from preschool to early adolescence: the Framingham Children's Study. International Journal of Obesity & Related Metabolic Disorders 27, 827–833.
Rachlin, H., 1995. The value of temporal patterns in behavior. Current Directions in Psychological Science 4, 188–192.
Rachlin, H., Raineri, A., Cross, D., 1991. Subjective probability and delay. Journal of the Experimental Analysis of Behavior 55, 233–244.
Reynolds, B., 2006. A review of delay discounting research with humans: relations to drug use and gambling. Behavioural Pharmacology 17, 651–667.
Reynolds, B., Schiffbauer, R., 2004. Measuring state changes in human delay discounting: an experimental discounting task. Behavioural Processes 67, 343–356.
Reynolds, B., Richards, J., DeWit, H., 2006. Acute alcohol effects on the Experiential Discounting Task and a question-based measure of delay discounting. Pharmacology, Biochemistry and Behavior 83, 194–202.
Richards, J.B., Zhang, L., Mitchell, S.H., 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, 121–143.
Saeki, D., Yamaguchi, T., Ito, M., 2002. The effect of reward amount on discounting of delayed rewards in rats. Japanese Journal of Psychonomic Science 21, 39–40.
Saunders, J.B., Aasland, O.G., Babor, T.F., de la Fuente, R.R., Grant, 1993. Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption. Addiction 88, 791–804.
Shamosh, N.A., DeYoung, C.G., Green, A.E., Reis, D.L., Johnson, M.R., Conway, A.R.A., Engle, R.W., Braver, T.S., Gray, J.R., 2008. Individual differences in delay discounting: relation to intelligence, working memory, and anterior prefrontal cortex. Psychological Science 19, 904–911.
Sturm, R., 2003. Increases in clinically severe obesity in the United States, 1986–2000. Archives of Internal Medicine 163, 2146–2148.
Sugiwaka, H., Okouchi, H., 2004. Reformative self-control and discounting of reward value by delay or effort. Japanese Psychological Research 46, 1–9.
Vuchinich, R.E., Simpson, C.A., 1998. Hyperbolic temporal discounting in social drinkers and problem drinkers. Experimental and Clinical Psychopharmacology 6, 292–305.
Weller, R.E., Cook, E.W., Avsar, K.B., Cox, J.E., 2008. Obese women show greater delay discounting than healthy-weighted women. Appetite 51, 563–569.