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Abstract

Objective—When given the choice between $100 today and $110 in one week, certain people are more likely to choose the immediate, yet smaller reward. The present study examined the relations between temporal discounting rate and body mass while accounting for important demographic variables, depressive symptoms, and behavioral inhibition and approach.

Methods—After having their heights and weights measured, 100 healthy adults completed the Monetary Choice Questionnaire, the Beck Depression Inventory-II, and the Behavioral Inhibition Scale/Behavioral Approach Scale.

Results—Overweight and obese participants exhibited higher temporal discounting rates than underweight and healthy weight participants. Temporal discounting rates decreased as the magnitude of the delayed reward increased, even when other variables known to impact temporal discounting rate (i.e., age, education level, and annual household income) were used as covariates.

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The authors have no competing interests.

Conclusion—A higher body mass was strongly related to choosing a more immediate monetary reward. Additional research is needed to determine whether consideration-of-future-consequences interventions, or perhaps cognitive control interventions, could be effective in obesity intervention or prevention programs.

Keywords

obesity; delay discounting; impulsivity; depression; behavioral inhibition; rewards; delayed gratification; risk factors

Introduction

Would you rather have $100 today, or $110 in one week? A person who chooses the immediate $100 reward is *discounting* the value of the additional $10. When choosing between rewards that vary in both immediacy and magnitude, tradeoffs occur in which the subjective value of the delayed reward decreases as the time to its receipt increases (Epstein et al., 2010). People suffering from impulse control disorders such as drug addiction, pathological gambling, and, debatably, obesity, tend to discount delayed rewards more rapidly than controls, including both rewards related to addictive substances as well as monetary rewards. (Bickel et al., 2012b; Bickel et al., 2012c; MacKillop et al., 2012).

Higher temporal discounting rates correspond with greater impulsivity and/or poorer executive function (Bickel, et al., 2012a). To date, the relations between temporal discounting rate and body mass are mixed. Some studies show that people with higher body mass discount more rapidly than those with lower body mass (Ikeda et al., 2010; Borghans et al., 2006; Bickel et al., in press). This relation, however, is typically demonstrated only in females (Davis et al., 2010; Fields et al., 2013; Weller et al., 2008) and was absent in a number of other studies (Manwaring et al., 2011; Nederkoorn et al., 2006). Most of the studies failing to demonstrate this relation, however, have used small sample sizes (e.g., fewer than 30 participants) or convenience samples (e.g., undergraduate students), or both. Moreover, studies of temporal discounting rate in obese people have yet to account for other psychological variables (e.g., response inhibition, depression) often found to relate to obesity (Luppino et al., 2010; Verdejo-Garcia et al., 2010). The purpose of the present study was to use a large, diverse sample to clarify relations between temporal discounting rate and these obesity-related phenomena.

The current study furthers our understanding of the relationship between body mass index (BMI) and temporal discounting rates by also considering key demographic variables such as education, income, and gender. Age, education, and income have been shown to influence temporal discounting rates (Green et al., 1996; Jaroni et al., 2004; Steinberg et al., 2009). We also considered individual differences in self-reported depression and behavioral activation/inhibition. Measures of depression were included due to the high comorbidity of depression and overweight or obesity (Faith et al., 2011). By contrast, individuals' patterns of activation/inhibition were examined because of the conceptual correspondence of those constructs to the two-system theories often thought to undergird delay discounting (e.g., Koffarnus et al., 2013).We hypothesized BMI would be significantly positively correlated

with temporal discounting rates, but that this relationship may be mitigated by education and/or income.

Materials and Methods

Participants

One hundred healthy adults (aged 18-55 years; M = 30.7 years; SD = 10.1; 49 females) were recruited from the Kansas City, Missouri area to participate in the present study, part of a larger study examining the neuroeconomics of controversial food technologies. It was a cross-sectional functional magnetic resonance imaging study examining consumer decisions about milk and egg products. Participants were recruited from both Kansas and Missouri using a variety of means, including online advertisements (i.e. Craigslist), flyers posted on the campus of the University of Missouri-Kansas City, and broadcast e-mails sent to the students, faculty, and staff of the University of Kansas Medical Center. In the state of Kansas, the population is composed of the following minorities: 5.7% Black , 0.9% American Indian or Alaskan native, 1.7% Asian, 7% Hispanic or Latino, 0% Native Hawaiian or other Pacific Islander, and 3.4% “other.” In the Kansas City metropolitan area, the population is composed of the following minorities: 30.5% Black, 0.8% American Indian or Alaskan native, 1.7% Asian, 16.8% Hispanic or Latino, 0% Native Hawaiian or other Pacific Islander, and 8.6% “other.” During recruitment, care was taken to ensure participants’ demographic characteristics were representative of the regional population. Participants were excluded from participation if they reported lactose intolerance, a vegan diet, any condition contraindicating magnetic resonance imaging, current use of psychotropic medication, current or past abuse of illicit substances, diagnosis of severe neurological or psychiatric illness, inability to read and speak English fluently, left- and mixed-handedness, and pregnancy.

Measures

Height, Weight, and Body Mass—Participants’ heights and weights were measured using a Perspective Enterprises stadiometer, model PE-WM-60-84, and a Befour scale, model PS6600 ST, respectively. Participants’ body masses (kg/m^2) were calculated using the body mass index (BMI) calculator provided by the Centers for Disease Control and Prevention, which defines body masses of less than 18.5 as “underweight,” of between 18.5 and 24.9 as “healthy weight,” of between 25.0 and 29.9 as “overweight,” and of greater than 29.9 as “obese.”

Education Level and Annual Household Income—Participants’ education levels and annual household incomes were measured by self-report.

Temporal Discounting Rate—Participants’ temporal discounting rates (k) were measured using the Monetary Choice Questionnaire (Kirby et al., 1999). This self-report questionnaire includes 27 questions, each of which solicits the respondent's preference for either of two monetary rewards: a smaller, immediate reward and a larger, delayed reward. Responses are used to calculate four temporal discounting rates for the respondent: one each for small, medium, and large reward sizes, and one across all reward sizes. Higher temporal

discounting rates correspond with greater impulsivity and/or poorer executive function (Bickel et al., 2012).

Depression—Participants' depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996). This self-report assessment includes 21 items, with higher scores indicating more depressive symptoms.

Behavioral Inhibition and Approach—Participants' abilities to regulate behavioral inhibition and approach were assessed using the Behavioral Inhibition Scale/Behavioral Approach Scale (BIS/BAS) (Carver et al., 1994). This self-report assessment includes 24 items that assess a person's tendency to avoid undesirable or unpleasant stimuli (i.e., inhibition) and, conversely, seek desirable or pleasant stimuli (i.e., approach). Responses are used to calculate scores along a single behavioral inhibition-related subscale and each of three behavioral approach-related subscales (i.e., drive, fun-seeking, and reward responsiveness).

Data Analysis

The following approach was used with data analysis. First, raw data from the delay discounting surveys were scored using the technique used by Kirby, Petry, and Bickel (1999). Consistent with prior research (Kirby et al., 1996), because temporal discounting rates are nonnegative and not normally distributed, their natural logs (ln[*k*]) were used for analyses. An analysis of variance (ANOVA) was then conducted comparing the log transformed discounting rates (i.e., ln[*k*]) for small, medium, and large rewards in under/healthy weight individuals (UH) to those in overweight/obese individuals (OO). Because ln(*k*) was significantly different between the UH and OO groups, yet variables known to interact with ln(*k*) (i.e., age [Green, et al. 1996; Steinberg et al., 2009], income [Green et al., 1996], and education [Jaroni, Wright, Lerman, & Epstein, 2004]) were uncontrolled, a general linear model comparing ln(*k*) for each reward type while co-varying out the influence of age, education, and income was conducted. The choice to use these variables as covariates was driven by previous research, however, in the present dataset, ln(k) was significantly correlated with education (rho = -0.29, $p = 0.004$) and BMI was significantly correlated with age (rho = 0.39, $p<0.001$) and the correlation between BMI and income approached significance (rho = 0.18, $p = 0.07$)

Next, because of prior studies showing that the relation between delay discounting rate and BMI interacts with gender (e.g., Weller et al., 2008), a two way ANOVA was conducted exploring effects of gender (i.e., male vs. female) and obesity status (i.e., UH vs. OO) on ln(*k*).

Spearman rank-order correlations were then conducted to examine relations between body mass, temporal discounting rate, and scores on the BDI-II and subscales of the BIS/BAS. Because the correlations between ln(*k*) and BDI-II scores and between ln(*k*) and a subscale of the BIS/BAS (i.e., funseeking) were significant, a stepwise linear regression was conducted to determine if a model incorporating ln(*k*), BDI-II scores, and BIS/BAS subscales would predict BMI. Finally, because ln(*k*) was the only variable that predicted BMI, yet BMI was significantly correlated with other variables (i.e., the behavioral

inhibition subscale of BIS/BAS), relations between ln(k) and our other variables were explored using a stepwise linear regression incorporating BDI-II scores and BIS/BAS subscales.

Results

Participants' body masses ranged from 18.4 to 50.1 (M = 26.35; SD = 5.33) and were underweight (n = 2), healthy weight (n = 49), overweight (n = 26), and obese (n = 23). Education levels were "high school" (n = 14), "associate's degree or some college" (n = 20), "bachelor's degree" (n = 49), and "graduate degree" (n = 17). Annual household incomes were less than $20,000 per year ($n$ = 34), between $20,000 and $39,999 per year ($n$ = 25), between $40,000 and $59,999 per year ($n$ = 20), between $60,000 and $79,999 per year ($n$ = 9), between $80,000 and $99,999 per year ($n$ = 7), and greater than $100,000 per year ($n$ = 4). Table 1 provides more detailed statistics describing participants' demographic characteristics, including age, sex, and race and ethnicity.

Participants' temporal discounting rates ranged from .0002 to .19 (M = .015; SD = .025), and their scores on the BDI-II fell, on average, within the non-depressed range (M = 4.94; SD = 4.95). Mean scores on the drive, fun-seeking, reward responsiveness, and behavioral inhibition subscales of the BIS/BAS were 11.81 (SD = 2.22), 11.80 (SD = 2.21), 17.51 (SD = 2.25), and 19.11 (SD = 4.16), respectively. Table 2 provides more detailed statistics describing participants' temporal discounting rates and scores on the BDI-II and subscales of the BIS/BAS.

Analysis of variance (ANOVA) revealed differences between underweight/healthy weight (UH) and overweight/obese (OO) participants in temporal discounting rates for small ($F_{[1, 99]}$ = 23.98, p = 0.001), medium ($F_{[1, 99]}$ = 26.02, p < 0.001), and large reward sizes ($F_{[1, 99]}$ = 18.89, p = 0.001). Relative to UH participants, OO participants featured consistently higher temporal discounting rates that decreased as the magnitude of the reward being discounted increased. Figure 1 shows the temporal discounting rates of UH participants (closed circles) and OO participants (closed squares). General linear models contrasting UH and OO participants' temporal discounting rates for small ($F_{[4, 95]}$ = 4.78, p = 0.001, η_p^2 = 0.17), medium ($F_{[4, 95]}$ = 5.31, p = 0.001, η_p^2 = 0.18), and large reward sizes ($F_{[4, 95]}$ = 6.19, p < 0.001, η_p^2 = 0.21) were statistically significant, even when other variables known to influence temporal discounting rate (i.e., age, education, and income) (Green et al., 1996; Jaroni et al., 2004; Steinberg et al., 2009) were used as covariates.

A two-way ANOVA examining differences in temporal discounting rates as a function of body mass (i.e., UH vs. OO) and sex found a significant main effect of body mass ($F_{[1,93]}$ = 9.21, p = 0.003, η_p^2 = 0.09), but no main effect of sex ($F_{[1,93]}$ = 0.57, p = 0.45, η_p^2 = 0.06) or interaction between body mass and sex ($F_{[1,93]}$ = 0.04, p = 0.842, η_p^2 < 0.01).

Table 3 shows the Spearman's rho correlations between body mass, temporal discounting rate, and scores on the BDI-II and subscales of the BIS/BAS. Body mass was significantly related to temporal discounting rate and score on the behavioral inhibition subscale of the BIS/BAS. Scores on the behavioral approach subscales were positively and significantly interrelated. In addition to its relation to body mass, as rates of temporal discounting

increased, scores on the fun-seeking subscale of the BIS/BAS and score on the BDI-II also increased. Lastly, as score on the BDI-II increased, so did score on the behavioral inhibition subscale of the BIS/BAS.

A stepwise linear regression model examining the degree to which temporal discounting rate, score on the BDI-II, and each of the scales of the BIS/BAS predicted BMI revealed that only temporal discounting rate significantly predicted body mass ($\beta = 0.31$, $t(99) = 6.53$, $p = 0.002$). This model accounted for a significant proportion of the variance in BMI scores ($R^2 = 0.10$, $F_{[1,98]} = 10.60$, $p = 0.002$). This model did not examine interactions amongst these variables. Still, these other behavioral variables may exert influence over body mass through their relation with temporal discounting rate. To examine this, a stepwise linear regression model using BDI-II score, and the subscales of the BIS/BAS to predict ln(k) was conducted. This analysis revealed that total scores on the BDI-II ($\beta = 0.35$, $t(96) = 3.75$, $p < 0.001$), fun-seeking subscale of the BIS/BAS ($\beta = 0.26$, $t(96) = 2.86$, $p = 0.005$), and behavioral inhibition subscale of the BIS/BAS ($\beta = -0.21$, $t(96) = -2.22$, $p = 0.03$) each significantly predicted temporal discounting rate as part of a model that accounted for significant variability in temporal discounting rate ($R^2 = 0.19$, $F_{[1,96]} = 7.72$, $p < .001$). This model did not examine interactions amongst these variables.

Discussion

The present study further elucidates relations between temporal discounting rate and body mass by examining the influence of other factors known to be associated with overweight and obesity and temporal discounting rate, including depression and behavioral inhibition and approach. Results revealed that one's temporal discounting rate is strongly associated with body mass, even when the influences of age, education level, annual household income, and sex are accounted for. Based on previously published studies, (Green et al., 1996; Jaroni et al., 2004; Steinberg et al., 2009), we hypothesized that education and/or income would mitigate the relation between obesity and temporal discounting rates, but found that even when controlling for these demographic variables, the significant association remained.

Obese and overweight adults demonstrate significantly higher temporal discounting rates than healthy weight adults; that is, obese and overweight individuals were much more likely to choose the immediate monetary reward. Further, more depressive symptoms and higher self-reported fun-seeking are associated with higher temporal discounting rates, while more self-reported behavioral inhibition is associated with lower rates. Temporal discounting rate accounts for unique variance in body mass, even after accounting for other variables, and obese and overweight adults report decreased ability to wait for a delayed monetary reward. This is among the first studies (see also Epstein et al, in press) to report such a robust relation between temporal discounting rates and body mass, even when taking into account other important demographic variables.

The present study had a number of strengths. First, the study provided an unambiguous demonstration of the relation between delay discounting and obesity. As noted in the introduction, the research on this relation has been mixed. This study was done in a community based sample, suggesting considerable generalizability of the present findings.

Second, this study is one of the first studies to systematically examine the relation between delay discounting rate and depression (i.e., BDI –II scores; cf. Yoon et al., 2007). Depression, as well as inhibition/activation (i.e., BIS/BAS), however, were not directly related to obesity. Because of the high comorbidity of depression and overweight or obesity (Faith et al., 2011), and the relations between BIS/BAS scores and various subtypes of obesity (Matton et al.., 2013) understanding the relations between these constructs may inform our understanding of obesity. In the present study, these variables only seemed to be related to BMI though their relation to delay discounting rate. Additional research, however, is needed to make strong statements about whether these relations are direct or indirect.

The current study, however, also has several weaknesses that can be addressed by future research. First, the present study did not examine relations between delay discounting and actual food intake or exercise. Previous studies, however, have suggested that there is a clear relation between food reward and food intake in non-obese women and discount at high rates, but not in non-obese women that discount at low rates (Rollins et al., 2010). Additional research more clearly linking delay discounting rates to food intake or exercise in obese individuals will allow stronger statements to be made. Second, additional variables with known relations to delay discounting rate (e.g., cigarette use) were not measured and accounted for in the present analysis. Future studies examining this will surely strengthen the conclusions that can be made. Other limitations include the use of a self-reported questionnaire of hypothetical monetary rewards, and a highly restricted range of depression scores in our particular sample. Future studies should also include discounting tasks with real monetary rewards.

One's temporal discounting rate is believed to be a relatively stable trait (Odum 2011), but researchers also posit it could be modified through training (Daniel et al., 2013a; Koffarnus et al., 2013). The present study further supports the notion that delay discounting rate in an appropriate target for intervention by providing an unambiguous demonstration of significant relations between delay discounting rate and BMI. A more complete understanding of the complex relations between body mass and temporal discounting rate could inform designs for obesity prevention and intervention programs aimed at helping people lower the rate at which they discount the value of future health benefits (Daniel et al., 2013b). Although promising research suggests modifying temporal discounting rates may improve behaviors related to weight loss (Best et al., 2012), future research into whether and how this rate can be altered, and whether doing so can increase healthy behaviors, is essential.

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Figure 1.

Temporal discounting rates of underweight and healthy weight participants (closed circles) and overweight and obese participants (closed squares) across reward sizes.

Table 1

Summary of demographic data.

	All participants (*n* = 100)	UH participants (*n* = 51)	OO participants (*n* = 49)
Age*	30.66 (10.10)	27.94 (8.26)	33.49 (11.10)
Sex			
Male	51	21 (41.2%)	30 (61.2%)
Female	49	30 (58.8%)	19 (38.8%)
Body mass*	26.35 (5.33)	22.47 (1.78)	30.27 (4.77)
Education level			
Grade school/Junior high	0	0 (0.0%)	0 (0.0%)
High school/GED	14	6 (11.8%)	8 (16.3%)
Associate's degree/Some college	20	6 (11.8%)	14 (28.6%)
Bachelor's degree	49	31 (60.8%)	18 (36.7%)
Graduate degree	17	8 (15.7%)	9 (18.4%)
Annual household income			
Less than $20,000	34	20 (39.2%)	14 (28.6%)
$20,000 to $39,999	25	7 (13.7%)	18 (36.7%)
$40,000 to $59,999	20	14 (27.5%)	6 (12.2%)
$60,000 to $79,999	9	5 (9.8%)	4 (8.2%)
$80,000 to $99,999	7	4 (7.8%)	3 (6.1%)
$100,000 to $119,999	1	0 (0.0%)	1 (2.0%)
$120,000 to $139,999	3	0 (0.0%)	3 (6.1%)
$140,000 or more	1	1 (2.0%)	0 (0.0%)
Race/ethnicity			
White/Caucasian	83	47 (92.2%)	36 (73.5%)
Black/African American	7	0 (0.0%)	7 (14.3%)
Hispanic	3	2 (3.9%)	1 (2.0%)
American Indian	0	0 (0.0%)	0 (0.0%)
Asian	7	2 (3.9%)	5 (10.2%)
Native Hawaiian/Pacific Islander	0	0 (0.0%)	0 (0.0%)
Other	0	0 (0.0%)	0 (0.0%)

*Mean values, with standard deviations in parentheses.

Table 2

Temporal discounting rates and scores on the BDI-II and BIS/BAS subscales.*

	All participants (*n* = 100)	UH participants (*n* = 51)	OO participants (*n* = 49)
Temporal discounting rate (&)**	.0149 (.0247)	.0074 (.0101)	.0227 (.0321)
BIS/BAS (Drive)	11.81 (2.22)	11.78 (2.19)	11.84 (2.27)
BIS/BAS (Fun-seeking)	11.80 (2.21)	11.69 (2.31)	11.92 (2.12)
BIS/BAS (Reward responsiveness)	17.51 (2.25)	17.69 (2.09)	17.33 (2.42)
BIS/BAS (Behavioral inhibition)	19.11 (4.16)	19.78 (4.10)	18.41 (4.15)
BDI-II	4.94 (4.95)	4.12 (4.26)	5.80 (5.49)

*Mean values, with standard deviations in parentheses.

**Higher temporal discounting rates correspond with greater impulsivity.

Table 3

Spearman's rho correlations between body mass, temporal discounting rate, and scores on the BDI-II and subscales of the BIS/BAS.

	1.	**2.**	**3.**	**4.**	**5.**	**6.**
1. Body mass	-	-	-	-	-	-
2. Temporal discounting rate (ln[*k*])	.308**	-	-	-	-	-
3. BIS/BAS (Drive)	.077	−.032	-	-	-	-
4. BIS/BAS (Fun-seeking)	.041	.220*	.430**	-	-	-
5. BIS/BAS (Reward responsiveness)	−.002	.143	.278**	.491**	-	-
6. BIS/BAS (Behavioral inhibition)	−.214*	−.070	−.187	.002	.186	-
7. BDI-II	.166	.233*	−.136	−.060	−.017	.203*

*$p < .05$

**$p < .01$