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Differential associations between obesity and behavioral measures of impulsivity



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ABSTRACT

A growing literature indicates that impulsivity is a fundamental behavioral process that underlies obesity. However, impulsivity is a multidimensional construct, which comprises independent patterns of decision-making that could be uniquely associated with obesity. No research to date has clarified whether obesity is differentially associated with specific behavioral aspects of impulsivity. This study examined whether obesity was differentially associated with patterns of decision-making associated with impulsivity—delay discounting, probability discounting, and response inhibition. Young adults ($n = 296$; 44.3% male) age 18–30 were recruited from the community with media advertisements. Participants completed a series of standard self-report measures of health outcomes and behavioral measures of delay discounting, probability discounting, and response inhibition individually in a laboratory. Associations between body mass index (BMI) and behavioral outcomes in the whole sample indicated that BMI was associated with age, delay discounting, and probability discounting, but not response inhibition. A logistic regression that included age, sex, and substance use as covariates found that delay discounting, but neither probability discounting nor response inhibition, was associated with obesity status. Sensitivity to delay, rather than response inhibition and sensitivity to uncertainty, may be the best correlate of obesity status in adults. These findings are relevant to our understanding of the fundamental behavioral processes associated with obesity.

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1. Introduction

Individual differences in sensitivity to features of food accessibility may be an important factor for understanding overeating and obesity. One such influence may be impulsivity. Impulsive individuals tend to make decisions quickly and without fully considering the consequences of their actions and have difficulties delaying gratification (Ainslie, 1975). A substantive literature makes a clear connection between patterns of impulsivity and obesity (e.g., Chalmers, Bowyer, & Olenick, 1990; Dezwaan et al., 1994; Jonsson, Bjorvell, Levander, & Rossner, 1986; Nasser, Gluck, & Geliebter, 2004; Williamson, Kelley, Davis, Ruggiero, & Blouin, 1985). However, impulsivity is a complex construct (Caswell, Bond, Duka, & Morgan, 2015; Evenden, 1999) associated with several different decision-making processes that may be

differentially associated with obesity. A clear picture of the behavioral mechanisms associated with obesity-related outcomes is fundamental to obesity treatment and prevention efforts.

One important aspect of impulsivity is an insensitivity to delayed outcomes, which is exhibited in difficulties with delaying gratification. Indeed, the development and maintenance of obesity may result from a preference for smaller, immediate outcomes and/or an insensitivity to larger, delayed consequences. One procedure designed to quantify insensitivity to delayed consequences is the delay-discounting task (e.g., Rachlin, Raineri, & Cross, 1991). Delay discounting describes the decrease in preference for a reward as a function of the delay to receiving it. In the laboratory, delay discounting is measured by presenting participants with choices between a hypothetical smaller-sooner reward (e.g., \$100 now) and a hypothetical larger-later reward (e.g., \$1000 in 1 year). The amount of the smaller-sooner reward is adjusted in subsequent questions until an indifference point that represents the current subjective value of the delayed outcome is established. When indifference points are gathered across several delays, they can be described using a hyperbolic decay function (Mazur, 1987): $V = A/(1 + bX)$. In

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this model, V is the indifference point, which is a function of the amount of the delayed reward (A) and the delay to its receipt (X). The rate of decay (b) is the primary dependent variable and captures how quickly the subjective value of the reward decreases as a function of time, and higher b values represent an increased rate at which the larger-delayed outcome loses value. Indeed, studies that have employed the hyperbolic decay function have found that obese participants devalue hypothetical food (Hendrickson & Rasmussen, 2013; Rasmussen, Lawyer, & Reilly, 2010) and money (Appelhans et al., 2011; Best et al., 2012; Bickel et al., 2014; Fields, Sabet, Peal, & Reynolds, 2011; Jarmolowicz et al., 2014; Weller, Cook, Avsar, & Cox, 2008) at steeper rates than do healthy-weight controls. In other words, obese individuals tend to have difficulty delaying gratification when the outcomes are food and money. Though these studies cannot establish directionality alone, they do suggest a common behavioral mechanism (i.e., delay discounting) is associated with overeating and obesity.

Risk-taking describes a tendency to engage in behavior that has a relatively high probability of a negative outcome and is associated with substance abuse (Lejuez, Bornovalova, Daughters, & Curtin, 2005), eating disorders (Boeka & Lokken, 2006), and sex-related behavior (Lawyer, 2013; Lawyer & Schoepflin, 2013; Lejuez et al., 2005; Lejuez, Simmons, Aklin, Daughters, & Dvir, 2004; Wardle, Gonzalez, Bechara, & Martin-Thormeyer, 2010). Obesity also is associated with risk-taking in that obese participants demonstrate risky patterns of decision-making on the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), a common measure of risk-taking (Brogan, Hevey, O'Callaghan, Yoder, & O'Shea, 2011; Brogan, Hevey, & Pignatti, 2010; Davis, Patte, Curtis, & Reid, 2010; Koritzky, Yechiam, Bukay, & Milman, 2012).

One measure of risk-taking that has received growing attention in the literature is the probability-discounting task (Green & Myerson, 2004). Probability discounting describes the decrease in preference for a reward as the odds against receiving it increase. In a typical probability-discounting task, participants are offered the choice between a hypothetical smaller-certain reward (e.g., \$100 for sure) vs. a hypothetical larger-risky reward (e.g., \$1000 at 50% chance). The individual subjective value of the larger probabilistic reward is then estimated by adjusting the amount of the smaller reward across a range of probabilities. When plotted as a function of the odds against receiving the larger reward, sensitivity to uncertainty can, like delay discounting data, be described using Mazur's (1987) hyperbolic-decay model described above. In probability discounting, V is the indifference point, A represents the amount of the larger uncertain reward, X represents the odds against receiving the large outcome (calculated as $[1/p]-1$, where p represents the probability of receiving the outcome) and b represents how quickly the subjective value of the large reward changes as a function of probability. In probability discounting, smaller b values indicate that the large, risky outcome loses its value at a relatively slow rate, indicating a tendency to choose the larger-risky over the smaller-certain reward. Only one study to date indicates a relationship between high body-fat percentage and probability discounting, finding that obese participants were more likely to prefer smaller-certain bites of food over larger-risky bites (Rasmussen et al., 2010), though this finding was not replicated in a follow-up study (Hendrickson & Rasmussen, 2013). These findings provide mixed findings regarding aversion to risky food-related outcomes in individuals with high body fat.

Another form of impulsivity is response inhibition, which refers to the ability to suppress, or stop, a prepotent response. Response inhibition deficits are associated with a range of problem health behaviors, including alcohol use (Carlson, Johnson, & Jacobs, 2010), drug use (Colzato, van den Wildenberg, & Hommel, 2007; Fu et al., 2008) and cigarette smoking (Billieux et al., 2010). Deficits in

inhibitory control have long been implicated in obesity (Wardle, 1988), where individuals have difficulty resisting impulses toward consuming food once presented with a food-related cue. Indeed, deficits in inhibitory control are associated with unhealthy eating (Jasinska et al., 2012), food intake in healthy women (Guerrieri et al., 2007), higher BMIs in adolescent girls (Batterink, Yokum, & Stice, 2010), and weight gain over a one-year period (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010). Several studies also indicate that obese children exhibit difficulties with response inhibition (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Verbeken, Braet, Claus, Nederkoorn, & Oosterlaan, 2009). However, no research to date compares response inhibition in obese versus healthy-weight men and women.

Although it is clear that various behavioral aspects of impulsivity are relevant to understanding the behavioral processes that are associated with obesity, no research to date has clarified whether some aspects of impulsivity are more directly relevant to obesity than others. Delay discounting, risk-taking, and response inhibition, while sharing similar qualities, tend to load onto different factors (Courtney et al., 2012) and account for different variances in health-related problems (Christiansen, Cole, Goudie, & Field, 2012). Among studies comparing different measures of impulsivity-related processes, most find that delay discounting tends to discriminate control participants from drug abusers (Torres et al., 2013), alcohol abusers (Courtney et al., 2012), and gamblers (Brevers et al., 2012; Ledgerwood, Alessi, Phoenix, & Petry, 2009; Torres et al., 2013) better than response inhibition and risk-taking (c.f., Christiansen et al., 2012; Fernie, Cole, Goudie, & Field, 2010; Ledgerwood et al., 2009). However, the extent to which these impulsivity-related processes are uniquely associated with obesity is unknown. A clear understanding of the specific behavioral processes associated with obesity is fundamental to prevention and intervention efforts.

The purpose of this study was to examine the degree to which delay discounting, probability discounting, and/or response inhibition are uniquely related to obesity in a community sample of young adults. Based on the extant literature, we hypothesized that all three measures would be significantly related to BMI and obese participants would exhibit more impulsive patterns of decision-making on all three measures, but that delay discounting would account for the most variance when all three measures were examined simultaneously.

2. Method

2.1. Participants

Unmarried adults ($n = 296$) between the ages of 18 and 30 were recruited via public advertisements to participate in a study concerning decision-making and health outcomes (see Table 2 for demographic information). Participants were compensated with \$25 and an option of entering their names in a lottery for several prizes for their participation. Data from five participants were excluded from data analysis due to technical errors in gathering weight data, preventing calculation of body mass index.

2.2. Procedure

After providing informed consent, participants completed all behavioral and self-report measures in a semi-private, screened-off section of the laboratory. Measures were counterbalanced such that half of the participants completed the self-report measures first and the other half completed the behavioral measures first. The order of behavioral measures also was counterbalanced across participants. All self-report measures were completed using a

Table 1

Comparison of residual sum of squares (fit of hyperbolic decay model) to individual data across tasks and weight status groups.

Discounting measure	Non-obese (N = 235)		Obese (N = 56)		Test statistics	
	Median (quartiles)	Mean (sum) rank ^a	Median (quartiles)	Mean (sum) rank ^a	U	p
Delay	.05 (.02, .09)	144.48 (33952.5)	.06 (.02, .10)	152.38 (8533.5)	6222.5	.53
Probability	.04 (.02, .11)	148.56 (34912.5)	.03 (.01, .09)	135.24 (7573.5)	5977.5	.29

^a Used for comparison using Mann–Whitney U.**Table 2**

Comparison of demographic, substance abuse, and impulsivity variables among obese and non-obese participants.

	Non-obese (n = 235)	Obese (n = 56)	Test statistic	df	p
Demographics					
% Male sex (N)	34.5 (19)	46.4 (109)	3.03 ^a	2	.22
Mean age (SD)	22.63 (3.64)	21.5 (3.30)	−2.20 ^b	288	.03
% College educated (N)	75.0 (42)	82.1 (193)	1.48 ^a	2	.48
% Caucasian (N)	86.3 (44)	86.1 (192)	.80 ^a	2	.67
Median substance abuse ^e (IQR)	−1.02 (−1.76, 1.12)	−.77 (−1.76, .85)	6147.5 ^c	–	.86
Mean impulsivity measures					
Delay discounting ^d (SD)	−5.87 (2.40)	−6.82 (2.05)	−3.01 ^b	289	.003
Probability discounting ^d (SD)	1.60 (2.17)	1.01 (1.72)	−1.90 ^b	289	.03
Response inhibition (SD)	284.99 (89.34)	281.48 (73.07)	−0.31 ^b	289	.76

^a Chi-square.^b Independent samples *t*.^c Mann–Whitney U.^d Natlog-transformed raw *b* values.^e SU = summary variable combining AUDIT, DUDIT, and FTND scores; IQR = Interquartile range.

computer program that presented questions and recorded responses into a database. This procedure maintained participant anonymity, which is important in light of the sensitivity of some of the questions asked. Similarly, all behavioral measures were administered using previously developed computer programs associated with each task. All procedures were approved by the Idaho State University Institutional Review Board and were administered by graduate and undergraduate research assistants.

2.3. Behavioral measures

2.3.1. Delay discounting

Delay discounting was measured using a computer program used in previous research (Baker, Johnson, & Bickel, 2003) and administered using a PC-compatible computer. Participants made a series of choices between a large monetary outcome after a delay (e.g., \$1000 in 6 months) and a smaller monetary outcome available immediately (e.g., \$100 right now). All choices were for hypothetical outcomes, and participants did not receive any of the rewards they chose. The computer program began by selecting a smaller-sooner amount at random from within a range established by two outer limits, which adjusted (in \$20 increments) until the smaller-sooner amount was subjectively equivalent to the larger-later amount (i.e., the indifference point was established) (Richards, Zhang, Mitchell, & de Wit, 1999). This procedure prevented an erroneous choice from incorrectly determining an indifference point by resetting the limits if a current response was inconsistent with previous responses and continued until indifference values were established across seven delays: 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years.

2.3.2. Probability discounting

Probability discounting was measured using the same computer program used for delay discounting. In this task, the individual made a series of choices between a large monetary outcome available with some probability (e.g., \$1000 with a 25% chance) and a smaller monetary outcome available with certainty (e.g., \$100 for sure). Using the same procedure described above, the computer

program adjusted the size of the smaller-certain amount until an indifference point was established across seven different probabilities: 95%, 75%, 50%, 25%, 10%, 5%, and 1%. Individual discounting patterns are characterized by plotting the indifference points against “odds against” receiving the larger outcome, which is $(1/p) - 1$, with p = probability of receiving the outcome.

2.3.3. Discounting script

Prior to completing the delay and probability discounting tasks, participants were read the following script [probability discounting language is in brackets]:

In this task you will be asked to make some decisions about which of two rewards you would prefer. One of the rewards will be available right now [for sure] and the other will only be available after you have waited for some period of time [with some probability]. For example, you might be asked to choose between \$100 delivered right now [for sure] and \$1000 delivered in one year [with a 25% chance]. The choices you make are completely up to you. You will not receive any of the rewards that you choose, but please make your decisions as though you were really going to get the rewards you choose.

2.3.4. Estimating discounting patterns

Patterns of discounting were quantified using each participant's rate of discounting (*b*) calculated by applying the hyperbolic decay function (Mazur, 1987) to individual indifference points using nonlinear regression in GraphPad Prism®. All *b* values were normalized using natlog-transformation. Residual sum of squares (RSS) was used as an indicator of how well the hyperbolic decay model described individual DD and PD indifference point data rather than R^2 values, which tend to yield uninterpretable (e.g., negative) values in the context of nonlinear regression (Johnson & Bickel, 2008).

2.3.5. Response inhibition

Response inhibition was measured using a stop-signal reaction time (SSRT) task (Logan, Schachar, & Tannock, 1997). This

computerized task, delivered via a PC-compatible computer, contained both a *go* task and a *stop* task. In the *go* task, participants were instructed to press one button when they saw an “X” on the screen and another button when they saw an “O” on the screen. In the *stop* task, participants were instructed to continue responding to the *go*-task cues, but not to respond when they heard a tone, which occurred on 25% of the *go*-task trials. Across *stop*-task trials, the delay to the stop signal was titrated according to the participant's performance until a delay was found at which the participant did not respond on 50% of the trials. The SSRT was measured by subtracting the final mean delay at which the tone was presented from the mean *go* reaction time (GRT; ms). Longer SSRTs are taken to indicate poorer response inhibition, or greater impulsivity. Non-signaled response times are used as an indicator of overall response times across participants.

2.4. Biometric measures

A Tanita BC-549 digital scale was used to measure weight (kg). Participant height (m) was measured using a standard tape measure mounted against a wall. Height and weight were used to calculate body mass index (BMI), which is calculated as: weight (kg)/height (m)². BMI was used to indicate if participants were underweight (BMI < 18.5), healthy weight (18.5 < BMI < 24.9), overweight (25.0 < BMI < 29.9) or obese (BMI ≥ 30).

2.5. Drug and alcohol abuse measures

In light of consistent empirical relationships between drug and alcohol use and behavioral measures of impulsivity (MacKillop et al., 2011), participants completed a series of associated measures. The Alcohol Use Disorder Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993) is a 10-item measure of harmful alcohol use, dependence, and problems with excellent psychometric properties (Reinert & Allen, 2002). Participants respond on a 0–4 scale indicating the frequency of alcohol use and problems. The total score used for the present study ranges from 0 to 40. The Drug Use Disorder Identification Test (DUDIT; Berman, Bergman, Palmstierna, & Schlyter, 2005) is an 11-item measure of harmful drug use and dependence with good reliability and sensitivity and is frequently used as a screen for drug-related problems. Participants respond on a 0–4 scale indicating the frequency of drug use and problems. The total score used for the present study ranges 0–44. The Fagerstrom Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) is a 6-item measure of nicotine dependence with excellent reliability and validity (Pomerleau, Carton, Lutzke, Flessland, & Pomerleau, 1994). Total scores used in this study range from 0 (least dependent smokers) to 10 (most dependent smokers). These measures are used frequently to assess problematic patterns of alcohol and drug use and nicotine dependence and were measured (total scores) to be included as covariates in analyses if group differences in one or more of these measures emerged.

2.6. Analytic plan

The relationships between obesity and impulsivity were established in three ways. First, independent-samples *t* and Mann–Whitney *U* tests were used to compare obese and non-obese participants across demographic, substance use, and impulsivity measures. Second, Pearson and Spearman correlations were calculated between BMI, substance use, and the three impulsivity measures. Age and substance use was assessed in these analyses to determine if they should be included as covariates in follow-up analyses given previous research (Green, Fry, & Myerson, 1994;

MacKillop et al., 2011). Finally, we conducted a logistic regression that determined which of the three behavioral measures of impulsivity were uniquely associated with participant classification into obese and non-obese categories.

3. Results

3.1. Delay and probability discounting model fits

Median (\pm IQR) RSS values for delay and probability discounting across weight status groups are presented in Table 1. We used Mann–Whitney *U* to compare RSS outcomes across tasks and weight status due to positive skewness in the distribution. Fit of the hyperbolic function to individual DD and PD data were not significantly different across weight status groups (see Table 1).

3.2. Weight status calculations and comparisons

Based on BMI calculations, participants were categorized as underweight ($n = 10$; 3.4%), healthy weight ($n = 147$; 49.7%) overweight ($n = 78$; 26.4%) and obese ($n = 56$; 18.9%). For purposes of analysis, underweight, healthy weight, and overweight participants were combined into a non-obese ($n = 235$) comparison group. The range of ages for both groups was 18–30. Table 2 compares obese and non-obese participants across demographic, substance use, and impulsivity variables. Obese participants were significantly older than non-obese participants and had higher *b* values for both delay and probability discounting. There were no differences in any other demographic, substance use, or impulsivity variables.

An independent-samples *t*-test comparing transformed discounting rates revealed that female participants ($M = 1.47$; $SD = 2.11$) had significantly greater rates of probability discounting than did male ($M = .66$; $SD = 1.25$) participants ($t = -4.08$, $df = 269$, $p < .001$), indicating more risk aversion among female participants. There were no significant sex differences on rates of delay discounting or response inhibition.

3.3. Correlations among variables

Correlations among the weight, substance use, and impulsivity measures are presented in Table 3. Due to constrained variability in the substance use measures, we created a latent substance use (SU) factor by summing each participant's *z*-scores across the AUDIT, DUDIT, and FTND. This increased variability in individual reports of substance use (but still yielded a skewed distribution) and also reduced the risk of Type I error due to multiple comparisons. BMI was modestly (range: .15–.19) and significantly (all p 's < .01) related to age, delay discounting, and probability discounting.

Table 3
Correlations among impulsivity, substance use, and obesity measures.

	Age	BMI	SU	DD	PD	RI
Age	–					
BMI	.19*** ^a	–				
SU	.13*** ^b	–.02 ^b	–			
DD	–.02 ^a	.19*** ^a	.11* ^b	–		
PD	.07 ^a	.15*** ^a	–.06 ^b	.19*** ^a	–	
RI	.02 ^a	.01 ^a	.02 ^b	.11 ^a	.02 ^a	–

BMI = Body Mass Index; SU = summary variable combining alcohol, drug, and cigarette use; DD = delay discounting natlog *b*; PD = probability discounting natlog *b*; RI = response inhibition.

* $p < .05$; ** $p < .01$.

^a Pearson's *r*.

^b Spearman's rho.

Likewise, delay and probability discounting were modestly and significantly correlated ($r = .19$; $p < .01$).

3.4. Logistic regression

To determine the extent to which delay discounting, probability discounting, and response inhibition are associated with membership in obese or non-obese weight groups, we conducted a logistic regression using individual natlog-transformed delay-discounting and probability-discounting b values and SSRTs drawn from the response inhibition measure. Age, sex, and substance use (the SU summary variable) were included in the model in light of the difference in age between obese and non-obese participants, the sex difference in patterns of probability discounting, and the relationships between substance use, age, and delay discounting. The Hosmer–Lemeshow test revealed that the model was a good fit for the data (χ^2 ($df = 8$) = 12.77, $p = .12$). Results of the regression (Table 4) indicate that age and delay discounting, but no other variable, were significantly associated with obesity status. Rate of delay discounting and indifference points (i.e., subjective value) across delays for obese and non-obese participants are in Fig. 1. Raw b (instead of log-transformed) values are presented for ease of interpretation. An independent-samples t -test confirmed that obese participants had significantly higher b -values for both delay discounting ($t = -3.01$ ($df = 289$), $p = .003$) and probability discounting ($t = -1.895$ ($df = 72.34$), $p = .03$). These figures indicate that obese participants exhibited more impulsive and risk-averse choice regarding delayed and probabilistic outcomes (respectively) than did non-obese participants.

4. Discussion

Several important conclusions can be drawn from the current study's findings and are important to consider in the context of identifying fundamental behavioral processes associated with obesity. First, our findings suggest that BMI is significantly related to both delay and probability discounting, but not response inhibition, in the general population. BMI was positively associated with rates of discounting for both delay and probability discounting, suggesting that, as body mass increases, individuals tend to devalue relatively large outcomes that are both delayed and probabilistic. Second, our findings suggest that obese participants exhibit more impulsive-choice patterns on the delay-discounting task and more risk-averse choice patterns on the probability-discounting task. We found no group differences on response inhibition. However, when potential confounds, such as age, sex, and substance use were considered, only performance on the delay discounting task was meaningfully associated with obesity status in this sample.

Our findings replicate numerous studies published to date indicating discounting is an important behavioral process that is associated with obesity (Appelhans et al., 2011; Best et al., 2012; Bickel et al., 2014; Fields et al., 2011; Jarmolowicz et al., 2014;

Weller et al., 2008). This effect is most prominent in the context of delay discounting, where obese participants exhibited more impulsive patterns of choice than did non-obese participants. These findings are consistent with others showing that obese participants discount the value of delayed money more than do non-obese participants (Appelhans et al., 2011; Best et al., 2012; Bickel et al., 2014; Fields et al., 2011; Jarmolowicz et al., 2014; Weller et al., 2008).

Although rate of probability discounting was correlated with BMI, the relationship between probability discounting and obesity status was non-significant after controlling for age, sex, and substance use. This is consistent with two other studies (Hendrickson & Rasmussen, 2013; Rasmussen et al., 2010) that found no relationship between percent body fat and probability discounting for money. However, Rasmussen et al. (2010) did report a clear relationship between obesity and probability discounting for food, which suggests that probability discounting may correlate with obesity, but only in the context of food-related outcomes. The findings herein also highlight another discrepancy in the empirical literature regarding obesity and behavioral measures of risk-taking. Our findings suggest that obese individuals do not differ from non-obese individuals in their risk aversion. This may seem inconsistent with studies indicating impaired performance on the Iowa Gambling Task (Brogan et al., 2011, 2010; Davis et al., 2010; Koritzky et al., 2012) among obese individuals, but performance on the IGT is weakly correlated with both delay (Dom, De Wilde, Hulstijn, & Sabbe, 2007) and probability (Olson, Hooper, Collins, & Luciana, 2007) discounting. Future research should consider whether obese participants exhibit differential patterns of behavior on various measures of risky choice.

Our finding that obese and healthy-weight individuals did not differ in terms of response inhibition suggests that this measure of impulsivity does not discriminate between obese and non-obese individuals. Though other studies examining response inhibition and obesity-related outcomes have found associations between response inhibition and obesity, these studies examined response inhibition only in relation to food intake (Guerrieri et al., 2007) and unhealthy eating (Jasinska et al., 2012). Only one study to date has reported a relationship between BMI and response inhibition (Batterink et al., 2010) and this was in adolescent girls. This is the first study to date to specifically compare obese and healthy-weight adults on a behavioral measure of response inhibition. In the absence of replicated relationships between response inhibition and BMI and/or obesity status, one conclusion could be that response inhibition is associated with broad food-related outcomes, but not necessarily with obesity per se.

Personality patterns like impulsivity are often thought of as broad patterns of behavior that transcend settings, but contemporary theories of personality make it clear that contextual (e.g., domain-specific) factors influence impulsive choice (Fleeson, 2001, 2004; Mischel & Shoda, 1998). The role of domain-specific patterns of response inhibition in health problem behavior is not well described, but a growing literature suggests that patterns of delay

Table 4
Summary of logistic regression analysis for impulsivity outcomes associated with obesity status controlling for age, sex, and substance use.

Variable	β	SE β	Wald's χ^2	df	p	Exp (B)	95% CI
Constant	-2.21	2.67	.69	1	.41	.11	
Age	.06	.08	.54	1	.46	1.06	.91–1.23
Sex	.50	.71	.49	1	.48	1.65	1.16–2.46
Substance use	.52	.29	3.20	1	.07	1.68	.95–2.97
Delay discounting	.53	.19	7.56	1	.006	1.69	1.16–2.46
Probability discounting	-.01	.19	.002	1	.97	.99	.69–1.43
Response inhibition	.004	.003	1.59	1	.21	1.00	.998–1.01

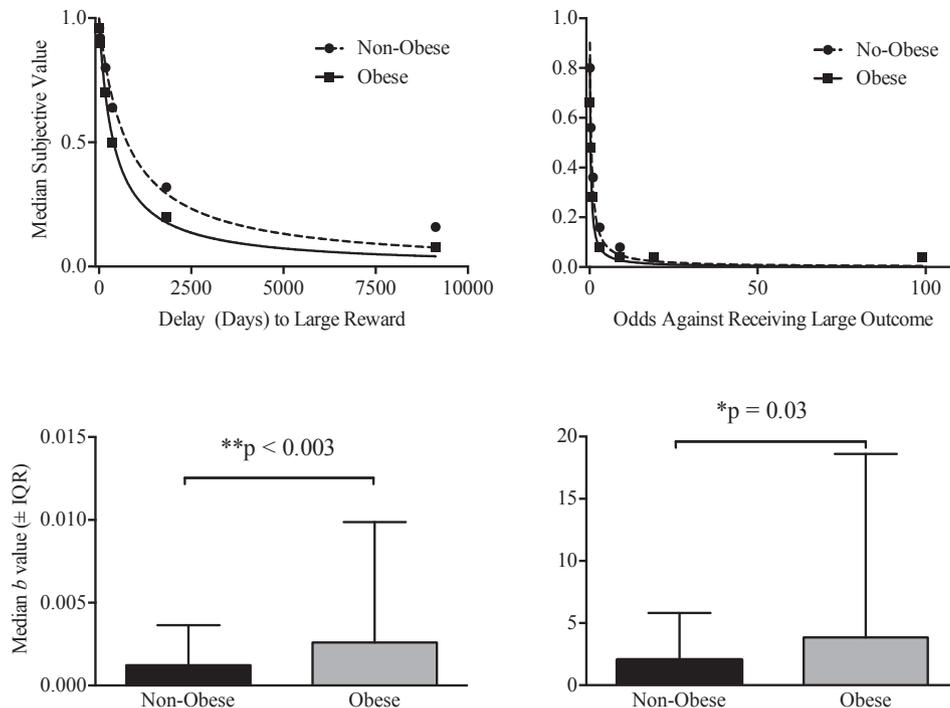


Fig. 1. Comparison of subjective values and discounting rate (b) parameters among obese ($n = 56$) and non-obese ($n = 235$) participants for delay (left panels) and probability discounting (right panels). IQR = Interquartile range; *Significance based on independent samples t -tests on natlog-transformed b values.

and probability discounting differ across outcomes (e.g., [Estle, Green, Myerson, & Holt, 2007](#)), including those for food. For example, [Rasmussen et al. \(2010\)](#) and [Hendrickson and Rasmussen \(2013\)](#) found discounting for food, but not money, was associated with high body fat. In light of research suggesting that deficits in response inhibition in the context of food-related cues are associated with obesity ([Batterink et al., 2010](#); [Jasinska et al., 2012](#)), future research should consider further developing the role of domain-specific patterns of impulsive action, which might provide important insights into the role of impulsivity-related behaviors in obesity.

There were some limitations to the present study. First, conclusions cannot be made on the direction of causality between obesity status and measures of impulsivity; one cannot conclude obesity causes increased delay discounting (or vice versa—increased delay discounting causes obesity) based on the present results. This limitation pervades much research that examines the types of behavior associated with obesity. However, the goal of the present study was to determine the extent to which behavioral measures of impulsivity were associated with obesity. Second, delay discounting is inversely related with high scores on measures of intelligence ([Shamosh et al., 2008](#)), working memory ([Shamosh et al., 2008](#)), and disordered eating ([Steinglass et al., 2012](#)). Though we assessed alcohol and drug dependence (variables that are related also to delay discounting; [MacKillop et al., 2011](#)) and found no difference between obese and healthy-weight participants, we did not include measures of intelligence, working memory, or eating disorder. Future research should consider controlling for these variables when examining differences in delay discounting between obese and healthy-weight participants. Third, and related to the previous limitation, some research suggests that age is related to discounting, where adults tend to be less impulsive than young adults and children ([Green et al., 1994](#)). As we found that obese participants were significantly older than non-obese participants (though only by one year, on average), it may have been that

age accounted for the differences in discounting we observed rather than obesity status. However, we do not believe this to be the case in the current study as age was neither associated with obesity status nor significantly associated with discounting. Future research may consider examining any interactions age and obesity may have on discounting.

Despite these limitations, the present study revealed important findings regarding impulsivity among obese and healthy-weight participants. The present study provides further support for both the notion that obesity is associated with impulsivity, and specific behavioral measures of impulsivity can differentiate among obese and healthy-weight individuals to a greater extent than others.

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