



## Research report

## Obese women show greater delay discounting than healthy-weight women

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## ABSTRACT

Delay discounting (DD) is a measure of the degree to which an individual is driven by immediate gratification vs. the prospect of larger, but delayed, rewards. Because of hypothesized parallels between drug addiction and obesity, and reports of increased delay discounting in drug-dependent individuals, we hypothesized that obese individuals would show higher rates of discounting than controls. Obese and healthy-weight age-matched participants of both sexes completed two versions of a DD of money task, allowing us to calculate how subjective value of \$1000 or \$50,000 declined as delay until hypothetical delivery increased from 2 weeks to 10 years. On both tasks, obese women ( $N = 29$ ) showed greater delay discounting than control women did ( $N = 26$ ;  $P$  values  $< .02$ ). Subsequent analyses showed that these differences were not related to differences in IQ or income. Obese ( $N = 19$ ) and healthy-weight ( $N = 21$ ) men did not differ significantly. Further research is needed to determine why greater delay discounting was not also observed in obese men.

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## Introduction

Obesity is increasing in prevalence and is a risk factor for many serious illnesses (Baskin, Ard, Franklin, & Allison, 2005; Ogden et al., 2006; Wyatt, Winters, & Dubbert, 2006). Recently, some investigators have emphasized the similarities between obesity and drug addiction (Davis, Levitan, Muglia, Bewell, & Kennedy, 2004; Del Parigi, Chen, Salbe, Reiman, & Tataranni, 2003; Pelchat, 2002; Volkow & Wise, 2005). Current neurobiological models have suggested that addiction is accompanied by dysfunctions in two brain circuits, one mediating impulsive behavior stemming from lack of inhibitory control and the other mediating oversensitivity to perceived drug cues (Jentsch & Taylor, 1999; Kolb, 1999; Robinson & Berridge, 2003; Volkow, Fowler, & Wang, 2004; Volkow, Fowler, Wang, & Swanson, 2004). Although obesity undoubtedly has a complex etiology, the same neural circuits dysfunctional in addicted individuals may be dysfunctional in some people who are obese (Alonso-Alonso & Pascual-Leone, 2007; Del Parigi et al., 2003; James, Gold, & Liu, 2004; Pelchat, 2002; Volkow & Wise, 2005; Wang, Vollkrow, Thomas, & Fowler, 2004). A number of observations support this view with regard to inhibitory control circuitry. Obese children are more likely to behave impulsively than children of normal weight (Braet, Claus, Verbeken, & Vlierbergh, 2007; Nederkoorn, Braet, Van Eijs,

Tanghe, & Jansen, 2006; Sigal & Adler, 1976; but see Bonato & Boland, 1983). A few studies have reported decision-making deficits in obese adults; however, studies using tasks related to impulsivity had possible confounding subject variables which make interpretation problematic (Davis et al., 2004; Gunstad et al., 2007; Pignatti et al., 2006).

A particularly useful task for studying decision-making has been the delay, or temporal, discounting of reward task (e.g., Bickel, Odum, & Madden, 1999; Bickel & Marsch, 2001; Raichlin, Raineri, & Cross, 1991; Vuchinich & Simpson, 1998). Delay discounting (DD) is a measure of being driven by immediate gratification vs. the willingness to wait for longer term or delayed rewards of greater magnitude. Individuals with various substance abuse problems involving cocaine, opiates, or alcohol; smokers; gamblers; individuals with some psychiatric conditions; and children show higher rates of delay discounting, meaning that they prefer smaller, immediate rewards more often than controls do (Alessi & Petry, 2003; Bickel et al., 1999; Crean, de Wit, & Richards, 2000; Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997; Mitchell, 1999; Petry, 2003; Reynolds, Richards, Horn, & Karraker, 2004; Scheres et al., 2006; Vuchinich & Simpson, 1998).

Some evidence supports a relationship between body mass index (BMI) and preference for sooner vs. later benefits (Smith, Bogin, & Bishai, 2005; Zhang & Rashad, 2008; but see Borghans & Golsteyn, 2006). One study that compared obese and non-obese women on a delay discounting task found no group differences (Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006), but did

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not consider the possible confounding variable of income, which may be an important influence on delay discounting (Green, Myerson, Lichtman, Rosen, & Fry, 1996). It is also possible that differences in IQ (de Wit, Flory, Acheson, McCloskey, & Manuck, 2007) obscured a potential obese and control difference in DD, although the groups did not differ in mean education (Nederkroon, personal communication). Because of the recently suggested parallels between drug addiction and obesity, we hypothesized that obese individuals would show greater delay discounting than controls in the absence of confounding effects of IQ and income.

## Methods

### Participants

Introductory psychology students ( $N = 1290$ ) were screened for eligibility during the initial week of classes. Inclusion criteria consisted of BMI  $\geq 30$  kg/m<sup>2</sup> (obese) or BMI of 18.5–24.9 kg/m<sup>2</sup> (controls), and age 18–50 years. Exclusion criteria included being a current or past smoker, having a current or prior substance abuse or gambling problem, having a current or past eating disorder based on the Eating Disorder Diagnostic Scale (EDDS; Stice, Telch, & Rizvi, 2000), having a serious health condition, having current or previous hallucinations or delusions, or taking medication that could affect thinking or emotion. An additional exclusion criterion for the controls was ever having a BMI  $>30$  kg/m<sup>2</sup>. Responses from the questionnaire were used to select obese and control participants matched on gender and on age, due to past findings suggesting that these factors affect DD performance (Green et al., 1996; Kirby & Maraković, 1996; Reynolds, Ortengren, Richards, & De Wit, 2006). Those eligible ( $N = 112$ ) were contacted and subsequently gave their informed consent for participation. We tested 57 healthy-weight (34 female, 23 male) and 55 obese (33 female, 22 male) participants. Table 1 shows the final group sizes after some were excluded as described below. All procedures involving research participants were approved by the UAB Institutional Review Board.

### Lab session

Participants were tested individually. A personal computer was used to present choices and record responses on a commonly used adjusting-amount, or titrated, version of a task measuring delay

**Table 1**  
Group  $N$ 's for participants included in the final data analysis and means for sociodemographic and dispositional variables

	Women		Men	
	Control	Obese	Control	Obese
$N$	26	29	21	19
C	14	11	11	9
AA	11	18	9	9
AS	1	0	1	1
BMI	21.9 (2.3)	38.4 (6.6)	22.3 (1.2)	35.4 (4.8)
Age	20.0 (2.6)	19.6 (2.9)	19.4 (1.5)	19.2 (1.3)
Income	50.9 (24.6)	39.8 (25.8)	55.8 (24.0)	51.1 (22.1)
Shipley	103.2 (7.7)	100.2 (7.6)	106.5 (6.6)	106.9 (7.0)
BIS total	63.8 (8.9)	61.8 (9.6)	63.9 (7.2)	63.0 (12.2)
BIS attention	18.8 (3.5)	17.7 (3.1)	17.6 (2.7)	17.9 (3.9)
BIS motor	21.1 (3.4)	19.9 (5.0)	21.2 (3.8)	21.6 (5.0)
BIS non-planning	23.8 (4.4)	24.2 (4.0)	25.1 (3.2)	23.5 (4.5)

Obese, BMI  $\geq 30$  kg/m<sup>2</sup>; Controls, 18.5  $\leq$  BMI  $\leq$  24.9 kg/m<sup>2</sup>; AA, African-American; AS, Asian; C, Caucasian; values shown for quantitative variables are means with standard deviations in parentheses; Income, parental household income in thousands of dollars; Shipley, Shipley Institute of Living Scale; BIS, Barratt Impulsivity Scale.

discounting of hypothetical amounts of money (Holt, Green, & Myerson, 2003). Hypothetical rewards were used because previous studies have shown that hypothetical monetary amounts produce results comparable to those obtained with real monetary amounts (Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003). Participants were asked in a series of trials to choose between two monetary amounts, a variable amount that could be received immediately and a fixed, larger amount to be received after varying delays. For each delay, the choices presented were titrated to quickly determine each indifference point, or that point at which the subjective value of the delayed reward was equal to the amount of the immediate reward (Johnson & Bickel, 2002; Madden et al., 2003).

Participants initially received 12 practice trials, followed by the experimental trials. Two versions of the task were used in which the delayed amount was \$50,000 or \$1000. Each participant received both versions of the task, and the presentation order of the two versions alternated between participants within each BMI group. Within each version of the task, participants were given six choices at each of seven delays, in the following order: 2 weeks, 1 month, 6 months, 1 year, 3 years, 5 years and 10 years. The first choice in the \$50,000 version of the task (DD-High) was between the delayed reward of \$50,000 and an immediate reward whose amount was half that of the delayed reward (i.e., \$25,000 now). In the \$1000 version of the task (DD-Low), the first choice was \$1000 later vs. \$500 now. For the next five choices, the immediate reward was varied based on the participant's previous choice, and the size of the adjustment got smaller with successive choices. In this way, the values of the immediate choices were assumed to converge on the subjective value of the delayed amount. The seventh choice was not presented, but the amount that would have been presented was used as the subjective value of \$1000 or \$50,000 if it were to be presented after the specified delay.

While in the lab to do the DD task, participants also had their height and weight measured (without shoes and wearing street clothes) for the actual BMI values used in the study, and had their IQ estimated using the Shipley Institute of Living Scale, which has been found to predict WAIS full scale IQ scores ( $r = .75$ , Zachary, Paulson, & Gorsuch, 1985). Some other studies have approached IQ more obliquely, by comparing DD in those attending college or not (Jaroni, Wright, Lerman, & Epstein, 2004) or by comparing students with higher or lower grades (Silva & Gross, 2004). However, our subjects were all college students, and many were freshman who did not yet have college GPA's. A brief income questionnaire was administered to determine average annual gross income of the household in which the participant was raised. Participants also completed the Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995), a widely used self-report scale with three subscales (attention, lack of planning or non-planning, and motor impulsivity).

### Analyses

The titration procedure resulted in a graph of each participant's monetary indifference points at the seven delays for the DD-High and the DD-Low tasks. Data from most participants exhibited the pattern shown for the group means in Figs. 2 and 3; that is, a monotonic, decreasing function for indifference points, or subjective values, vs. delay. Some participants appeared to misunderstand the task, as indicated by gross departures from this typical pattern by showing, for example, large fluctuations or increases, rather than decreases, in subjective value as delay increased. Data were excluded from any participant who showed such departures on both of the DD tasks. In this way, data from 7 obese participants and 10 controls were excluded. As an indication that this procedure

introduced no bias, we found that results of group comparisons were essentially identical whether or not these participants were included in the data analysis; that is, obese women, but not obese men, discounted significantly more than controls did on both DD tasks (see Results). Table 1 shows final group sizes and demographic characteristics of the obese and healthy-weight groups.

Overall discounting was assessed using an area-under-the-curve (AUC) analysis, which has been suggested as a theoretically neutral measure of discounting (Myerson, Green, & Warusawitharana, 2001). For each DD task performed by each participant, AUC standardized to fall between 0 and 1 (Myerson et al., 2001) was calculated for the plot of subjective values vs. delay, with lower values indicating greater discounting. Because group distributions of AUC's were typically skewed, statistical analyses were performed on  $\log_e$  AUC values. These were compared between groups and tasks using analysis of variance (ANOVA) with BMI (Group) and Gender as between-groups factors and Task (DD-Low or DD-High) as a within-group factor. We used Gender as a factor because gender differences on the DD task have sometimes been reported (Kirby & Maraković, 1996; Reynolds et al., 2006; for review see de Wit et al., 2007). Simple-effects analyses were performed for separate comparisons of obese vs. control participants of each gender.

We did not index individuals' discount rates using estimates of the hyperbolic free parameter  $k$  (Mazur, 1987), but values of  $k$  based on group means for subjective values were calculated for use as descriptive statistics to allow comparisons with results of other studies. We used nonlinear regression to fit the hyperbolic function  $SV = A/(1 + kD)$ , where SV is the subjective or discounted value of a reward ( $A$ ) presented after a delay ( $D$ ).

To more specifically assess group differences as a function of delay, mixed between-group (BMI and Gender) and within-group (Delay) analyses of variance (ANOVA) were performed on subjective values for each DD task. For group comparisons at specific delays, Holm's procedure was used to maintain family-wise  $\alpha = .05$  (one-tailed; Holm, 1979).

ANOVA was also used to compare groups on sociodemographic and dispositional variables with simple-effects analyses to compare obese and control groups within each gender.

## Results

### Delay discounting performance

#### Comparison of AUC's

ANOVA on  $\log_e$  AUC's revealed a nonsignificant main effect of BMI ( $F[1,91] = 2.82, P = .097$ ), but a significant BMI  $\times$  Gender interaction ( $F[1,91] = 5.81, P = .018$ ; Fig. 1; see also Figs. 2 and 3). Subsequent simple-effects analyses showed greater discounting in obese women compared to healthy-weight women overall ( $P = .002$ ) as well as on the individual DD tasks ( $P = .011$  and  $.002$  for DD-Low and DD-High, respectively). No such differences were seen for men ( $P$  values  $>.40$ ). Because DD performance has been found to be related to IQ (de Wit et al., 2007), age (Green, Fry, & Myerson, 1994; Green et al., 1996), and income (Green et al., 1996), we also compared the groups after partialling Shipley scores, age, and reported household income. Results were essentially unchanged; that is, obese women discounted more strongly than control women on both tasks ( $P$  values  $<.03$ ). Parenthetically, because racial differences in DD performance have been reported (de Wit et al., 2007), we also performed ANOVA's like those described above but also incorporating Race as a factor and using data from Caucasians and African-Americans only. Results of the obese vs. control comparisons were essentially unchanged and no

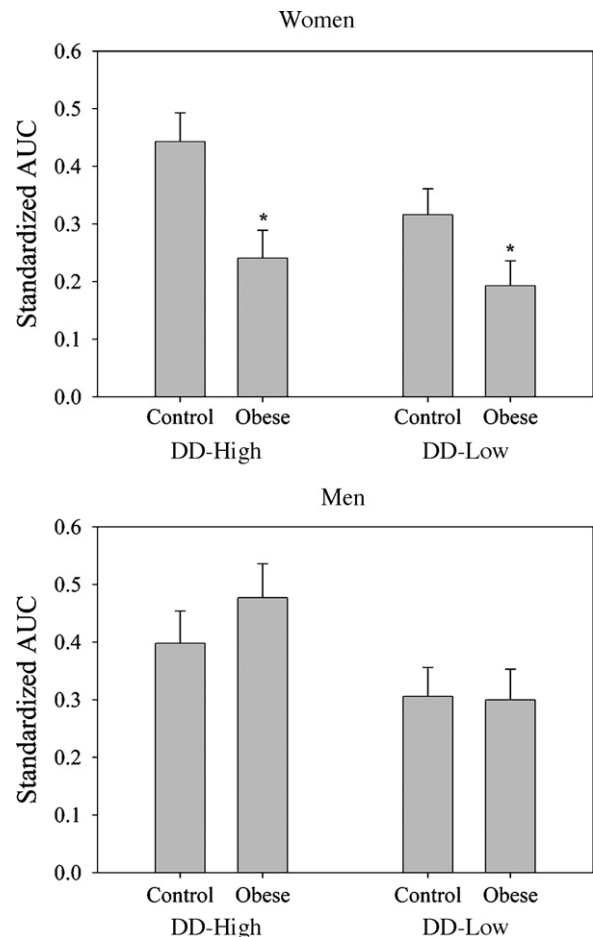


Fig. 1. Mean (with S.E.M.) standardized areas under the curve (AUC's) of experimental groups on the DD-High and DD-Low tasks. \* $P < .05$  for difference between  $\log$ -transformed AUC values for control and obese women.

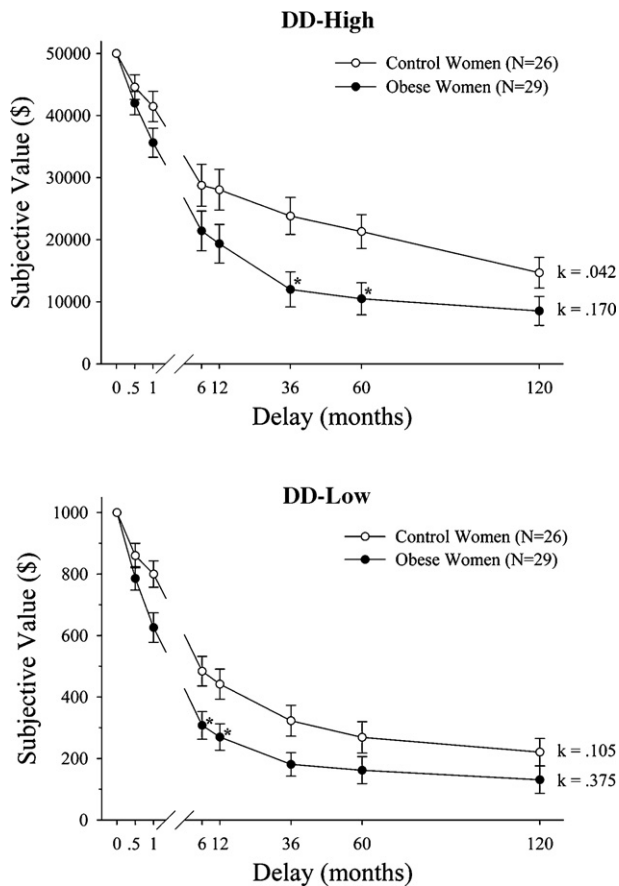
interactions involving the Race factor approached significance ( $P$  values  $>.10$ ).

ANOVA revealed a significant effect of Gender ( $F[1,91] = 4.38, P = .039$ ), such that AUC's were lower overall for women, indicating greater discounting. In light of the significant BMI  $\times$  Gender interaction (see above), it is worth noting that this effect was carried by the obese women. Control women did not differ significantly from either group of men ( $P$  values  $>.75$ ), whereas AUC's of obese women were significantly lower than both control men and obese men ( $P$  values  $<.01$ ).

It is apparent from Fig. 1 that standardized AUC's were generally lower on the DD-Low task compared to DD-High. This impression is confirmed by ANOVA comparing standardized AUC's on the two tasks. The main effect of Task (High vs. Low) was significant ( $F[1,91] = 24.80, P < .0001$ ). This comparison replicates the magnitude effect, or the finding that smaller delayed rewards are discounted more steeply than larger rewards (e.g., Estle, Green, Myerson, & Holt, 2006; Green, Myerson, & McFadden, 1997; Johnson & Bickel, 2002).

#### Comparison of subjective values

In light of results from the AUC analyses, we compared profiles of subjective values across delays for obese vs. control women and obese vs. control men. For women (Fig. 2), the effect of BMI was significant for both DT-High ( $F[1,53] = 5.54, P = .022$ ) and DT-Low ( $F[1,53] = 7.20, P = .01$ ). Obese women discounted the hypothetical reward of \$50,000 to a significantly greater extent than control



**Fig. 2.** Mean ( $\pm$ S.E.M.) subjective values as a function of delay until receipt of a hypothetical large (DD-High, \$50,000; top graph) or smaller (DD-Low, \$1000, bottom graph) reward for the two groups of women. Subjective value is the amount of an immediate reward judged equal in value (the indifference point) to a larger delayed reward. For clarity, the X-axis scale is expanded for delays of 0–1 month. \* $P < .05$  by Holm's test for comparison of obese vs. control women.  $k$ , discount parameter estimates calculated from fit of hyperbolic function to group means of subjective values.

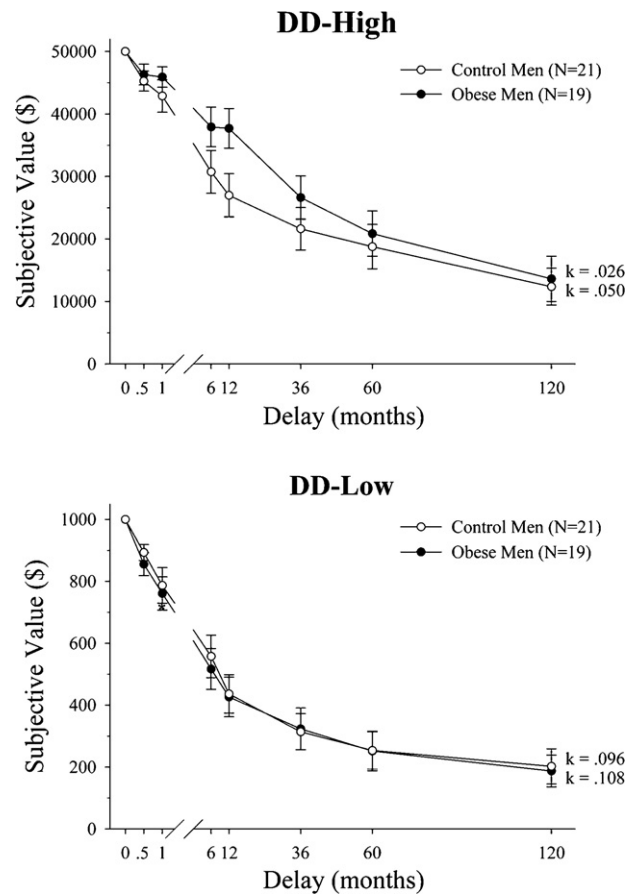
women did at 36 and 60 months and the \$1000 reward at 6 and 12 months ( $P$  values  $< .05$ ). For men (Fig. 3), neither the BMI effect nor the Group  $\times$  Delay interaction approached significance for either DD task ( $P$  values  $> .20$ ). Values of  $k$  based on group means for subjective values are shown in Figs. 2 and 3. For the obese women, these values were 3–4 times as great as for the control women.

#### Sociodemographic variables

Obese and control women did not differ significantly with regard to age ( $P = .55$ ) or household income, although obese women tended to have lower household incomes ( $P = .10$ ; Table 1). Likewise, there were no differences between the two groups of men on these variables ( $P$  values  $> .50$ ).

#### Dispositional variables

Scores on the Shipley Institute of Living Scale were not significantly different between obese and control participants of either gender ( $P$  values  $> .10$ ; Table 1). We also observed no group differences on the BIS scales ( $P$  values  $> .10$ ). Parenthetically, there were no significant correlations between DD performance measures and the BIS scales whether for each gender or men and women combined ( $P$  values  $> .05$ ).



**Fig. 3.** Mean ( $\pm$ S.E.M.) subjective values as a function of delay until a hypothetical large (DD-High, \$50,000; top graph) or smaller (DD-Low, \$1000, bottom graph) reward is received for the two groups of men. Other conventions as in Fig. 2.

## Discussion

Our results supported our hypothesis that obese individuals would display higher rates of delay discounting, or choose more immediate but smaller monetary rewards than controls, but this result was found only for the women. Subsequent analyses indicated that the delay discounting difference between obese and control women was not related to differences in age, income, or IQ. This is the first study to reveal delay discounting deficits in obese individuals and the first study to show decision-making deficits in obese individuals when the possible confounding variable of income was considered. A previous study that used a delay discounting task with hypothetical monetary rewards did not find group differences between obese and control adult women on the discounting parameter  $k$  (Nederkoorn, Smulders et al., 2006). Although no sample characteristics were described except for age and the groups did not differ on education (Nederkoorn, personal communication), possible differences in income (Green et al., 1996) may have obscured finding group differences. Differences between the results of the present study and that of Nederkoorn, Smulders et al. (2006) could also be related to different ages of participants, with theirs being older (mean age = 41 years), or to minor methodological differences in the DD task used. A more recent study by Yeomans, Leitch, and Mobini (2008) also found no relationship between BMI and performance on a delay discounting task, but their sample of 147 women included only 3 obese and 28 overweight individuals and mentioned matching groups on age only. Nederkoorn et al. did

find group differences in both obese vs. normal-weight adults and children on a stop signal task used to measure response inhibition, with obese showing poorer inhibition (Nederkoorn, Braet et al., 2006; Nederkoorn, Smulders et al., 2006).

Another decision-making task that has revealed differences related to BMI is the Iowa Gambling Task (IGT). This paradigm was originally constructed by Bechara et al. to characterize the types of decision-making deficits found in those with ventromedial prefrontal cortex damage in terms of risk-taking and balancing of gains and losses (Bechara, Damasio, Damasio, & Anderson, 1994). It has subsequently been extended for use in those with various addictive disorders (e.g., Mazas, Finn, & Steinmetz, 2000; Monterosso, Ehrman, Napier, O'Brien, & Childress, 2001; Petry, Bickel, & Arnett, 1998). Davis et al. (2004) found that poorer decision-making on the IGT was correlated with higher BMI in adult women. A subsequent study using the IGT more directly compared obese (BMI >34) and healthy-weight subjects matched on age, education, and IQ, and found that the obese group did not learn to choose more advantageously over trials, unlike the controls (Pignatti et al., 2006).

Although we found a main effect of gender on DD, this result was due to the greater delay discounting of the obese women compared to the other groups. Performance by control women was similar to that shown by both groups of men. The results of previous studies of DD that addressed possible gender differences have been inconsistent. A large sample of middle-aged adults studied by de Wit et al. showed no gender difference on DD, nor did smaller samples of college students or adolescents (de Wit et al., 2007; Kollins, 2003; Reynolds, Karraker, Horn, & Richards, 2003). However, some studies have reported women to discount more steeply than men (Logue & Anderson, 2001; Reynolds et al., 2006), whereas one study found men to discount more steeply than women (Kirby & Maraković, 1996). A gender difference was also found in a meta-analysis of related delay of gratification tasks, with females better able to delay gratification than males (Silverman, 2003).

For the DD-High task, values of  $k$  computed from group mean subjective values were .042 vs. .170 (a ratio of 1:4) for control and obese women, respectively. Corresponding values for DD-Low were .105 vs. .375 (1:3.6). On the DD-High and DD-Low tasks,  $k$  values for both obese and control men were very similar to those for the control women (cf. Figs. 2 and 3). Thus, the obese women exhibited rates of discounting that were several-fold greater than those of the other three groups. These differences compare favorably to those that have been reported in comparisons of discount rates by controls vs. methamphetamine addicts (1:3.5; Monterosso et al., 2007), heroin addicts (1:1.9; Kirby et al., 1999), problem drinkers (1:5.8; Vuchinich & Simpson, 1998), and smokers (1:4.4; Reynolds et al., 2004).

Do our DD results for obese individuals have ecological validity; that is, do they relate to real-world choices involving immediate gratification vs. future outcomes? One might imagine that a cognitive problem leading to obesity could involve assigning higher subjective value to consumption of appealing, fattening foods at the present time than to potential long-term consequences of effective weight management, such as improved health in the future. What might actually be occurring in the brain is suggested by the intriguing results of a neuroimaging (PET maps of cerebral blood flow) study done in successful dieters vs. non-dieters by Del Parigi et al. The successful female dieters had reduced their BMI from at least 35 to 25 kg/mg<sup>2</sup> and maintained the weight loss for at least three months, whereas non-dieters were not following any weight loss program and had not had any changes in their weight for at least three months (Del Parigi et al., 2007). After ingesting a satiating amount (50% of their daily resting

energy expenditure) of a liquid meal, the successful dieters had greater activation in dorsal prefrontal cortex compared to the non-dieters. This result was interpreted by the authors as relating to greater top-down cognitive control or restraint related to inhibiting feelings associated with eating, given that a meal's worth of calories had already been consumed. In other studies, Le et al. (2006, 2007) found that obese women and men showed less postprandial activation in dorsolateral prefrontal cortex than normal-weight individuals. Presumably, obese individuals with greater delay discounting would also show less dorsal prefrontal cortex activity in situations requiring delay of gratification, perhaps especially in right prefrontal cortex (Alonso-Alonso & Pascual-Leone, 2007). Other abnormalities might also be found in obese individuals performing a DD task, as fMRI studies of delay discounting done in those with alcohol and methamphetamine addiction reported additional differences in patterns of activation compared to controls (Boettiger et al., 2007; Monterosso et al., 2007).

What is so different about obese women compared to non-obese women and obese or non-obese men that could explain their greater delay discounting in our study? Both BMI- and gender-related differences in personality traits may provide an explanation. Studies have suggested that there are gender differences on the Three Factor Eating Questionnaire (TFEQ) disinhibition (D) scale (Stunkard & Messick, 1985), with men scoring lower than women (Boerner, Spillane, Anderson, & Smith, 2004; Provencher, Drapeau, Tremblay, Després, & Lemieux, 2003). Disinhibition is defined as the tendency to overeat in response to various stimuli or situations. There is a strong positive relationship between disinhibition scores and high BMI, weight gain, and response to hedonic food cues (e.g., Bellisle et al., 2004; Provencher et al., 2003; Yeomans et al., 2008; for review see Hays & Roberts, 2008). Critically, women displaying higher scores on the TFEQ-D scale were found to perform more impulsively on the DD task (Yeomans et al., 2008). Thus, it is possible that particularly high disinhibition accounts for the greater delay discounting exhibited by the obese women in our study. The question of whether this gender difference in DD exists for other addictive or impulsive disorders has not been pursued, as most such studies have small patient samples and results from males and females have been combined.

The finding of greater delay discounting in obese compared to healthy-weight women may be tapping into a trait that is a factor leading to development of obesity in women; that is, being more likely to value smaller immediate rewards over greater delayed rewards. Alternatively, obesity may result in brain structural abnormalities (Haltia et al., 2007; Pannacciulli et al., 2006; Ward, Carlsson, Trivedi, Sager, & Johnson, 2005), possibly because of concomitant medical conditions (Wyatt et al., 2006), which subsequently affect delay of gratification. A longitudinal study would be better able to disentangle these relationships.

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