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Mindful Eating Reduces Impulsive Food Choice in Adolescents and Adults

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Idaho State University

Objective: The present study tested the extent to which age and obesity predicted impulsive choices for food and monetary outcomes and tested how a brief mindful-eating training would alter delay discounting for food and money choices compared with control groups. ***Method:*** First, 172 adolescents (M_{age} = 13.13 years) and 176 (M_{age} = 23.33 years) adults completed the Food Choice Questionnaire (FCQ) and Monetary Choice Questionnaire (MCQ) as measures of food and money delay discounting, respectively. Then, participants returned to the lab and were randomly assigned to complete a brief mindful-eating training, watch a DVD on nutrition, or serve as a control. Participants completed the FCQ and MCQ again as a postmanipulation measure. ***Results:*** Participants with high percent body fat (PBF) were more impulsive for food than those with low PBF. Adults with high PBF were also more impulsive for money compared with adults with low PBF; no PBF-related differences were found for adolescents. Participants in the mindful-eating group exhibited more self-controlled choices for food, but not for money. The control conditions did not exhibit changes. ***Conclusion:*** The study suggests that individuals with high PBF make more impulsive food choices relative to those with low PBF, which could increase the risk of obesity over time. It also is the first to demonstrate shifts in choice patterns for food and money using a brief mindful-eating training with adolescents. Mindful eating is a beneficial strategy to reduce impulsive food choice, at least temporarily, that may impede weight gain.

Keywords: adolescents, delay discounting, impulsivity, mindful eating, obesity

Supplemental materials: http://dx.doi.org/10.1037/hea0000440.supp

Overweight and obese adults exhibit greater impulsivity and sensitivity to food rewards compared with normal-weight controls (e.g., Hendrickson & Rasmussen, 2013; Mobbs, Crépin, Thiéry, Golay, & Van der Linden, 2010; Rasmussen, Lawyer, & Reilly, 2010). *Impulsivity* is a complex, multifaceted construct that consists of a number of mechanisms, including difficulties in response inhibition and riskiness (Bari, Robbins, & Dalley, 2011; Lawyer, Boomhower, & Rasmussen, 2015; Mobbs et al., 2010). One component is a preference for smaller, sooner over larger, later rewards—also known as *delay discounting* (Ainslie, 1975).

Delay discounting refers to a decrease in value of a reward as a function of the delay to its delivery (Ainslie, 1975; Kirby, Petry, & Bickel, 1999). In the delay-discounting task, participants make choices between a smaller outcome delivered immediately (e.g., five bites of food now) and a larger outcome delivered after a delay (e.g., 10 bites in 1 hr). A tendency to prefer smaller rewards over larger rewards as measured by an index of sensitivity to delay (k value) represents greater impulsivity (see Madden & Bickel, 2010 for details).

Kelsie L. Hendrickson and Erin B. Rasmussen, Department of Psychology, Idaho State University.

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Correspondence concerning this article should be addressed to Erin B. Rasmussen, Department of Psychology, Idaho State University, Pocatello, ID 83209-8112. E-mail: rasmerin@isu.edu

Delay Discounting Across the Life Span

Some studies have suggested that impulsive decision making for money decreases significantly with age (Green, Fry, & Myerson, 1994; Green, Myerson, Lichtman, Rosen, & Fry, 1996). Steinberg et al. (2009) found that children and young adolescents (13 years and younger) demonstrated steeper discounting patterns compared with individuals 16 years and older. In a more recent study, de Water, Cillessen, and Scheres (2014) found that age was positively related to waiting for larger, later monetary rewards in a population of 12- to 27-year-olds. Other studies have also shown a very similar pattern (e.g., Liu et al., 2016; Olson, Hooper, Collins, & Luciana, 2007; Prencipe et al., 2011), although some have not (e.g., Lamm, Zelazo, & Lewis, 2006). Differences in delay discounting between children and adults may be related to fewer experiences with long delays or that children have fewer opportunities to access monetary rewards compared with adults. In addition, the human prefrontal cortex, which is highly influential in self-controlled decision-making matures around 20 years old (Diamond, 2002), whereas, reward-related areas in the limbic system that are involved in more impulsive behaviors (i.e., striatum, nucleus accumbens) mature much earlier (Casey, Jones, & Hare, 2008). Of note, studies measuring delay discounting patterns across the life span have been limited to a small number and almost exclusively using money as the outcome commodity.

Discounting, Food, and Obesity

A number of studies report a significant relation between discounting and obesity in adult populations (e.g., Davis, Patte, Curtis, & Reid, 2010). For example, Weller, Cook, Avsar, and Cox

(2008) found that obese adult women exhibited stronger patterns of monetary discounting than healthy-weight women. Jarmolowicz et al. (2014) also showed similar results with a sample of men and women. Other studies have shown than obesity status predicted steeper discounting patterns for food-related outcomes in humans (Hendrickson & Rasmussen, 2013; Hendrickson, Rasmussen, & Lawyer, 2015; Rasmussen et al., 2010) and in an animal model (Boomhower, Rasmussen, & Doherty, 2013). It has been argued that a pattern of eating impulsively is likely a mechanism related to obesity (Rasmussen, Robertson, & Rodriguez, 2016) and is consistent with a reinforcer pathology view of health problems (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Carr, Daniel, Lin, & Epstein, 2011).

Studies have also examined the relationship between weight status and delay discounting patterns in youth. In one study, obese adolescent smokers exhibited steeper discounting rates for monetary outcomes than healthy-weight adolescent smokers (Fields, Sabet, Peal, & Reynolds, 2011). Best et al. (2012) found that overweight children who found food highly reinforcing and discounted monetary rewards steeply were more likely to be resistant to a 16-week family based obesity treatment. Taken together, delay discounting appears to be a psychological process related to obesity across the life span. Specifically, the ability to delay gratification to rewards influences our daily choice patterns; this is especially helpful in environments where self-control of energy consumption is required to maintain a healthy body weight.

Decreasing Impulsive Choice: Acceptance-Based Strategies

One component of several evidenced-based therapies that may be relevant to food-related behavior, especially impulsive food choices and overeating, is the employment of mindfulness. *Mindfulness* encompasses the idea of "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally" (Kabat-Zinn, 1994, p. 4). Mindfulness, as adapted to eating behavior, is termed *mindful eating* and is defined as, "a nonjudgmental awareness of physical and emotional sensations associated with eating" (Framson et al., 2009, p. 1439). It includes attention to moment-to-moment observations of visual stimuli, taste, satiety cues, and private events (e.g., thoughts) associated with the eating experience. It allows individuals to experience their external and internal environment while also slowing the pace of food consumption, increasing the chances of satiety before an excess of calories have been consumed (Cassell & Gleaves, 2006).

Within the last decade, empirical support for the clinical use of mindfulness has risen dramatically (see Olson & Emery, 2015, and O'Reilly, Cook, Spruijt-Metz, & Black, 2014 for recent reviews). Some well-supported uses include chronic pain (e.g., Kabat-Zinn, 1982), medication adherence (e.g., Gregg, Callaghan, et al., 2007), stress (e.g., Roberts & Danoff-Burg, 2010), depression- and anxiety-related symptoms (e.g., Evans et al., 2008; Kuyken et al., 2008) and disordered eating (e.g., Courbasson, Nishikawa, & Shapira, 2011; Lavender, Jardin, & Anderson, 2009; Proulx, 2008). Related to obesity, Lillis, Hayes, Bunting, and Masuda (2009) found that a 6-hr mindfulness and acceptance-based workshop lowered obesity-related stigma, psychological distress, and importantly, and body mass at 3-month follow up. Other studies show similar outcomes with reduction in weight and cravings and increases in physical activity (e.g., Alberts, Mulkens, Smeets, & Thewissen, 2010; Tapper et al., 2009). Hendrickson and Rasmussen (2013) examined the effects of a 50-min mindful-eating training session on impulsive choice patterns for hypothetical food. Adults completed computerized discounting tasks before and after either a 50-min mindful-eating workshop or watching an educational DVD. Individuals who completed the mindful-eating session discounted food less steeply than their baselines, whereas those who watched the educational video discounted similarly to baselines.

The Current Study

The present study was twofold: (1) it tested the extent to which measures of obesity predicted impulsive choice patterns for food-related and monetary outcomes across two age groups (adolescents ages 12 to 15 and college students) in an experimental setting, and (2) it determined the degree to which mindful-eating training affected impulsive choice patterns for food and money. Therefore, we tested the following hypotheses:

Hypothesis 1: Adolescents would exhibit more impulsive food-related and monetary choices compared with young adults.

Hypothesis 2: Obese individuals would be more impulsive for food-related and monetary outcomes compared with normal-weight individuals regardless of age.

Hypothesis 3: Regardless of age and obesity status, participants who completed a mindful-eating workshop would exhibit less impulsive food choice patterns compared with baseline measures. Participants in both control groups would not change relative to baseline.

Method

Participants

Participants were recruited for two sessions. A total of 348 participants (n = 214 female) participated in the baseline portion of the study, which included 172 adolescents (n = 88 females; M_{age} = 13.13, SD = 1.08) and 176 adults (n = 126 female; M_{age} = 23.33, SD = 6.95). Most participants reported European American/white ethnicity (78.7%) and presented with a wide range of body mass indices (range = 14.70 to 47.00) and body fat percentages (range = 6.40 to 53.70). Approximately 93% of participants (n = 324; n adolescents = 164; adults = 160; 61% female) adhered to the protocol and returned to the lab within 21 days for the second session.

Adults were undergraduate students recruited from introductory psychology courses at a rural university. Adolescent participants were recruited from two local schools, a youth organization mailing list, Craigslist, and a mass e-mail associated with a local newspaper. All participants were asked to not eat or drink at least two hours before each session. Participants who endorsed pregnancy, diabetes, HIV, AIDS, and/or hemophilia were excluded from the study.

Materials

Participants completed a series of self-report measures, including a demographics questionnaire, the Drug Abuse Screening Test (DAST) for adults (Skinner, 1982) or the DAST-A for adolescents (Martino, Grilo, & Fehon, 2000), the Alcohol Use Disorders Identification Test−C (AUDIT-C; Bush, Kivlahan, McDonell, Fihn, & Bradley, 1998), the Slosson Intelligence Test−Revised (3rd ed. [SIT-R3]; Slosson, Nicholson, & Hibpshman, 1990), and the Subjective Hunger Questionnaire to control for variables that have been shown to affect the rate of discounting (e.g., Kollins, 2003; Petry, 2001; Shamosh & Gray, 2007).

Health measures. Participants were measured for height, weight, body fat percentage, blood glucose level, and waist circumference. Percent body fat was measured by a Tanita 2204 Body Fat Scale, which uses bioelectrical impedance analysis, a valid and reliable method compared with alternative body composition techniques (e.g., Jebb, Cole, Doman, Murgatroyd, & Prentice, 2000; Rubiano, Nunez, Gallagher, & Heymsfield, 1999). Body mass index (BMIs) were determined by dividing the participant's weight in kilograms by height in meters squared (kg/m^2). For individuals 18 years and older, adult BMI categories were based on the Centers for Disease Control and Prevention [CDC] (2012a) standard weight status categories. For individuals 17 years and younger, BMI-for-age categories were used (CDC, 2012b). Blood glucose levels were determined via a blood glucose monitor (Accu-Chek® Compact Plus), which has sufficient accuracy and precision (Thomas, Kane, Bakst, Busch, Hamilton, & Abelseth, 2008) to help ensure little to no food or caloric liquid consumption occurred prior to the experiment.

Discounting measures. Participants were read delay-discounting task instructions (adapted from Kirby et al., 1999 and Rasmussen et al., 2010). Discounting measures were presented in a paper-and-pencil format.

Food Choice Questionnaire (FCQ). The participants were presented with a 5/8-in. cube that represented a standard bite of their favorite food before completing the FCQ. The FCQ is a 27-item task that was modified from the Monetary Choice Questionnaire (MCQ) using hypothetical food outcomes. It has been validated as a measure of food discounting (see Hendrickson et al., 2015). The nine questions associated with the medium outcome size were presented for the current study (e.g., "Would you prefer 15 bites now or 35 bites in 6 hours?").

MCQ. Similar to the FCQ, a modified version of the MCQ (Kirby & Maraković, 1996) was used. Participants made choices between two monetary rewards across nine items that assessed delay discounting with medium magnitude outcomes (e.g., "Would you prefer $40 now or $55 in 62 days?").

Procedure

Session 1. Participants entered an office-sized room or an open room with partitions to ensure confidentiality. Participants received an overview of the study, and then provided informed consent. They next completed baseline measures and reported the last time they ate and drank. Height, weight, percent body fat, waist circumference, and blood glucose were measured. Participants also completed the questionnaires and baseline measures of the FCQ and the MCQ. The order of biometric, questionnaires, and discounting tasks were counterbalanced to reduce order effects. Participants were scheduled to return within three weeks for the second part of the experiment. The average interval between sessions was eight days for both age groups.

Session 2. Participants independently signed up to participate in Session 2 "workshops," which were dependent on age (i.e., half of the groups were for adolescents only and the other half were for adults only). Participants were not informed about the title or content of the workshop prior to Session 2 to reduce selection bias. The condition for each group was randomized by computer-generated number tables prior study commencement. The mean group size for adolescents and adults was 7.45 individuals (SD = 2.77, group range = 3 to 12) and 9.63 (SD = 2.60, group range = 6 to 14), respectively. Participants again reported the last time they ate and drank and provided a small sample of blood to determine blood glucose levels.

Conditions. Participants were randomly assigned to either one of three conditions: mindful eating, DVD control, or standard control. In mindful-eating condition, participants completed a 50-min workshop on mindful eating and consumed four types of foods (see the online supplemental materials for more details). In the DVD-control condition, participants watched a 50-min DVD on nutrition and the food pyramid to control for exposure to food cues. Participants assigned to the standard control group did not engage in any type of training or structured activity. Participants in latter two control groups consumed the same types of foods as the mindful-eating condition; however, they ate the food at their own pace and were not given any further instructions. No groups discussed weight-loss strategies or set up weight-loss goals.

For compensation, undergraduate adults received course credit. Adolescents chose between a small prize and an entry into a drawing for one of several $20 gift cards.

Data Analysis Notes

Discounting scoring. For each participant, k estimates, a measure of discounting, were derived from the MCQ and the FCQ (see Kirby & Marakovic, 1996 and Hendrickson et al., 2015 for scoring). A higher k represents higher impulsivity. If responses were inconsistent, the geometric mean was used.

Statistical analysis. Data were analyzed using IBM® SPSS 22.0©. Missing data were handled by multiple Bayesian imputation and intent-to-treat analyses were used. Participants who missed Session 2 were placed in the control condition, and the last observation carried forward (LOCF) method was used unless otherwise noted. We conducted analyses using all responders unless otherwise noted. Because the distribution of k values were non-negative and positively skewed, values were log-transformed, a consistent practice with discounting data (e.g., Kirby & Maraković, 1996). First, differences between money and food outcomes were analyzed. Analyses of covariance (ANCOVAs) were conducted to examine obesity quartile differences in discounting after controlling for covariates that have been shown to influence discounting. Quartiles in the sample reflect different classifications of obesity such that those in the low PBF quartile fell between 6.4% to 19.4 (considered either underfat or healthy), and those in the high PBF quartile fell between 34.4% and 53.7% (considered obese across gender and age groups; see Gallagher et al., 2000; McCarthy, Cole, Fry, Jebb, & Prentice, 2006). Last, hierarchical

linear regression analyses were conducted to determine if a model incorporating PBF across all individuals predicted discounting.

Results

Baseline Demographics

Table 1 provides a summary of participants' demographic characteristics by total sample and adolescents and young adults separately.

There were significant demographic and biometric differences between adults and adolescents including adults having higher PBFs, $t(346) = -4.66$, $p < .001$, $d = 0.50$, and waist circumferences, $t(314.53) = -7.23$, $p < .001$, $d = 0.78$, than adolescents. In addition, on the basis of BMI percentile, 25.0% of adolescents ($n = 43$) were overweight and 13.4% ($n = 23$) were obese. For adults, on the basis of BMI, 27.8% ($n = 49$) were overweight and 29.5% ($n = 52$) were obese.

Baseline Monetary Discounting

Age × Percent Body Fat. Figure 1 shows monetary discounting rates (log-transformed k values for adolescents and adults with low and high PBF). A 2 (Age: adolescents vs. adults) × 2 (PBF: lowest vs. highest quartile) between-subjects factorial analysis of variance (ANOVA) revealed a main effect of age, such that adolescents preferred smaller, sooner amounts of money (i.e., discounted money more steeply) compared with adults ($M = -2.36$, $SD = 0.75$), $F(1, 170) = 3.98$, $p = .048$, $\eta^2 = 0.02$. There was not a significant main effect for PBF ($p > .05$); however, there was a statistically significant interaction between age group and PBF, $F(1, 170) = 8.41$, $p = .004$, $\eta^2 = 0.05$. Post hoc analyses revealed that adults, but not adolescents, in the highest PBF quartile discounted money more than did adults in the lowest PBF quartile, $t(34.68) = -3.08$, $p = .004$, $d = 1.05$.

To account for all participants and control for other variables known to influence delay discounting for money, a hierarchal linear regression examined the degree to which age (continuous variable) and PBF (continuous variable) uniquely predicted monetary delay-discounting rate controlling for covariates. Gender, AUDIT total score, DAST total score, and cognitive functioning were entered in the first step while age and PBF were entered in the second step (see Table 2). Gender, AUDIT, DAST, and IQ significantly predicted monetary discounting, $F(6, 340) = 4.95$,

Table 1
Summary of Demographic Data in Means (SEM) for Variables Across Age Groups for all Participants

	All participants	Adolescents	Adults	*p*
Demographic	(N = 348)	(n = 172)	(n = 176)	
Age	18.29 (.38)	13.13 (.08)	23.33 (.52)	<.001
Sex[a]				<.001
Male	134 (38.5%)	84 (48.8%)	50 (28.4%)	
Female	214 (61.5%)	88 (51.2%)	126 (71.6%)	
BMI	24.71 (.32)	22.18 (.35)	27.18 (.45)	<.001
PBF	26.72 (.55)	24.22 (.77)	29.16 (.73)	<.001
Waist circumference (cm)	84.36 (.88)	78.36 (.96)	90.25 (1.34)	<.001
Annual household income				
<$10,000			28 (15.9%)	
$10,000−$20,000			17 (9.7%)	
$20,000−$30,000			29 (16.5%)	
$30,000−$40,000			19 (10.8%)	
$40,000−$50,000			13 (7.4%)	
$50,000−$60,000			15 (8.5%)	
$60,000−$70,000			6 (3.4%)	
$70,000 or more			31 (17.6%)	
Race/ethnicity[a]				<.001
White/Caucasian	274 (78.7%)	143 (83.1%)	131 (74.4%)	
Black/African American	8 (2.3%)	2 (1.2%)	6 (3.4%)	
Hispanic	31 (8.9%)	6 (3.5%)	25 (14.2%)	
Asian	9 (2.6%)	3 (1.7%)	6 (3.4%)	
American Indian	5 (1.4%)	4 (2.3%)	1 (.6%)	
Other	20 (5.77%)	14 (8.1%)	7 (4.0%)	
Subjective hunger (0–100)	42.30 (1.45)	40.89 (2.00)	43.67 (2.11)	>.25
Glucose level	90.90 (.59)	92.33 (.87)	89.53 (.78)	.02
Hours since last meal	6.73 (.28)	5.64 (.33)	7.80 (.43)	<.001
Hours since last snack	4.88 (.20)	4.06 (.23)	5.68 (.33)	<.001
Full scale IQ	99.12 (.60)	99.78 (.98)	98.46 (.71)	>.25
Fagerström nicotine score	.27 (.06)	.03 (.02)	.50 (.11)	<.001
AUDIT-C score	.95 (.10)	.10 (.04)	1.78 (.17)	<.001
DAST score	.45 (.06)	.23 (.05)	.66 (.11)	<.001
Reported eating disorder[a]	1 (.3%)	0 (.0%)	1 (.6%)	>.25
Reported ADHD[a]	26 (7.5%)	16 (9.3%)	10 (5.7%)	.17

Note. BMI = body mass index; PBF = percent body fat; AUDIT-C = Alcohol Use Disorders Identification Test−C; DAST = Drug Abuse Screening Test; ADHD = attention-deficit/hyperactivity disorder.
[a] Frequency, with percentages in parentheses.

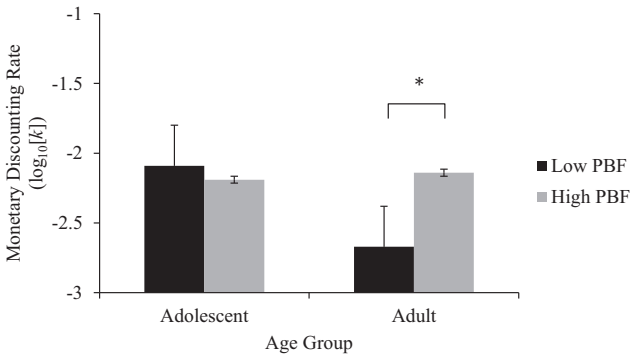

Figure 1. Log_{10} transformed mean (± SEM) monetary delay-discounting rates of adolescents (left; $n = 91$) and adults (right; $n = 83$) who fell within the lowest (black; adolescent $n = 62$, adult $n = 25$) and highest (gray; adolescent $n = 29$, adult $n = 58$) quartile across all participants. ($n = 174$, * $p < .01$.) PBF = percent body fat.

$p < .001$. The addition of age and PBF led to a statistically significant increase in variance in the model, $\Delta R^2 = 0.05$, $F(2, 340) = 8.31$, $p < .001$.

Adolescents. We also analyzed adolescent and adult data independently given differences in delay-discounting rates and health outcomes including BMI and PBF. Independent t tests confirmed that adolescents in the lowest PBF quartile had lower PBF, BMI, BMI percentile, and waist circumferences than adolescents in the highest PBF quartile, ps < 0.001. There were more males in the lowest PBF quartile ($n = 40$; 93%) and more females in the highest PBF quartile ($n = 36$; 84%), $\chi^2(1, N = 86) = 51.10$, $p < .001$. There were no other statistically significant demographic or heath variable differences between PBF quartiles (ps > 0.05). To examine monetary discounting differences between adolescent lowest and highest PBF quartiles, a one-way ANCOVA was conducted. Discounting in adolescents with high PBF was not significantly different than adolescents with low PBF, $F(1, 81) = 3.18$, $p = .079$. The covariates of gender, age, and hours since last meal were not statistically significant in the model (ps > 0.10).

Adults. To examine PBF differences in adults only, a series of independent t tests were conducted. Analyses showed that there were statistically significant differences between the two PBF quartiles with the lowest PBF group having statistically lower PBF, BMI, waist circumference, and age (ps < 0.001). Chi-square analyses for categorical dependent variables revealed that more adults in the lowest PBF quartile endorsed an annual income greater than $30,000 (50th percentile for entire sample) compared with the highest PBF quartile, $\chi^2(1, N = 81) = 4.35$, $p < .001$. There were significantly more females in the highest PBF quartile ($n = 41$; 93%) compared with men ($n = 3$; 7%), whereas the lowest PBF had equal numbers of females ($n = 22$; 50%) and males ($n = 22$; 50%), $\chi^2(1, N = 88) = 20.17$, $p < .001$. There were no other statistically significant differences between lowest and highest PBF groups with regard to demographic and health variables (ps > 0.05). A hierarchical linear regression on all data in the adult sample revealed that PBF scores predicted monetary discounting even after controlling for age, gender, and income (first step), $\Delta R^2 = 0.09$, $F(4, 171) = 5.91$, $p < .001$, $\beta = 0.36$, $t = 4.28$, $p < .001$. Gender, $\beta = -0.18$, $t = -2.23$, $p < .05$, and age, $\beta = -0.28$, $t = -3.66$, $p < .001$, were found to be statistically significant covariates whereas income was not.

Table 2
Regression Summary Predicting Monetary Discounting

Variable	b (SE)	β	t	R^2	ΔR^2	p
		Step 1				
				.03	.03	.03
Constant	−1.33 (.38)		−3.51			.001
Gender	−.20 (.08)	−.13	−2.40			.02
AUDIT-C	.03 (.02)	.08	1.34			*ns*
DAST	−.07 (.04)	−.11	−1.80			.05
Full-scale IQ	−.01 (.01)	−.12	−2.27			.02
		Step 2				
				.08	.05	<.001
Constant	−1.36 (.38)		−3.58			<.001
Gender	−.26 (.09)	−.17	−2.83			.01
AUDIT-C	.05 (.02)	.11	1.93			.06
DAST	−.07 (.04)	−.10	−1.75			*ns*
Full-scale IQ	−.01 (.01)	−.10	−1.86			.06
Age group	−.02 (.01)	−.22	−3.74			<.001
PBF	.01 (.01)	.165	2.53			.01

Note. AUDIT-C = Alcohol Use Disorders Identification Test−C; DAST = Drug Abuse Screening Test; PBF = percent body fat.

Baseline Food Discounting

Age × Percent Body Fat. Figure 2 shows food delay-discounting rates for adolescents (left) and adults (right) based on lowest and highest PBF quartiles across the entire sample.

A 2 (Age: adolescents vs. adults) × 2 (PBF: lowest vs. highest quartile) between-subjects factorial ANOVA revealed a main effect of PBF on discounting, $F(1, 170) = 7.63$, $p < .006$, $\eta^2 = 0.05$, in which adolescents with higher PBF discounted food more steeply than those with lower PBF. There was no significant main effect of age ($p = .10$) or interaction ($p > .25$).

A hierarchal linear regression was conducted across all participants to show the degree to which age (continuous variable) and PBF (continuous variable) uniquely predicted food delay-discounting rate above and beyond gender and subjective hunger.

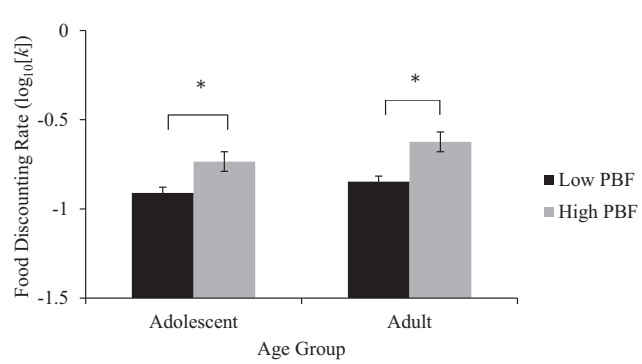

Figure 2. Log_{10} transformed mean (± SEM) food delay-discounting rates of adolescents (left; $n = 91$) and adults (right; $n = 83$) who fell within lowest (black; adolescent $n = 62$, adult $n = 25$) and highest (gray; adolescent $n = 29$, adult $n = 58$) quartile across all participants. ($n = 174$; * $p < .01$.) PBF = percent body fat.

Covariates were entered in the first step while age and PBF were entered in the second step (see Table 3). The full model of gender, subjective hunger, age, and PBF to predict food discounting was statistically significant, $F(4, 343) = 6.97$, $p < .001$. The addition of age and PBF to the prediction of food discounting led to a statistically significant increase in variance accounted for, $F(2, 343) = 3.97$, $p = .02$. BMI data, without PBF in the model, predicted similar outcomes.

Adolescents. Analyses for food discounting were conducted on adolescent and adult data separately. High PBF adolescents discounted food marginally more than low PBF adolescents, even when gender, age, and subjective hunger were controlled for, $F(1, 79) = 3.26$, $p = .07$, $\eta^2 = 0.05$. To determine the extent to which the full range of adolescent PBF predicts delay discounting for food, a hierarchical regression analysis was conducted with age, gender, subjective hunger, and IQ in the first step and PBF in the second step. Here, PBF did not significantly predict food discounting, $\beta = 0.01$, $t = 1.49$, $p = .13$. When PBF was replaced with BMI, BMI approached statistical significance, $\beta = 0.013$, $t = 1.72$, $p = .086$.

Adults. Adults with high PBF discounted food more steeply than did adults with low PBF, even when gender, income, and subjective hunger were controlled, $F(1, 83) = 4.78$, $p = .032$, $\eta^2 = 0.05$. Similar to adolescent data, we assessed how the full range of adult PBF impacts delay-discounting rate for food using linear regression. When only PBF was entered in the model, it was statistically significant, $\beta = 0.16$, $t = 2.15$, $p = .03$. A hierarchical linear regression analysis was conducted on all adults in the sample with age, gender, subjective hunger, IQ, and time since last snack and meal, in the first step and PBF in the second step. PBF remained statistically significant in the model, $\beta = 0.17$, $t = 2.00$, $p = .047$, with subjective hunger being the only significant covariate, $\beta = 0.31$, $t = 4.02$, $p < .001$.

Mindful Eating Data

There were no significant differences among conditions for baseline monetary discounting, $F(2, 345) = 0.22$, $p = .80$, or food discounting, $F(2, 345) = 0.44$, $p = .64$. Figure 3 shows pre- and postdiscounting data for hypothetical food across the three conditions for only adolescents (top) and for all participants (bottom).

Table 3
Regression Summary Predicting Food Discounting

Variable	*b* (*SE*)	β	*t*	R^2	ΔR^2	*p*
		Step 1				
				.054	.054	<.001
Constant	−1.00 (.05)		−18.80			<.001
Gender	.17 (.05)	.19	3.65			<.001
Subjective hunger	.01 (.01)	.15	2.84			.004
		Step 2				
				.075	.02	.02
Constant	−1.19 (.09)		−13.83			<.001
Gender	.11 (.05)	.12	2.10			.044
Subjective hunger	.01 (.01)	.16	3.00			.003
Age group	.04 (.03)	.07	1.23			*ns*
PBF	.05 (.03)	.13	2.05			.015

Note. PBF = percent body fat.

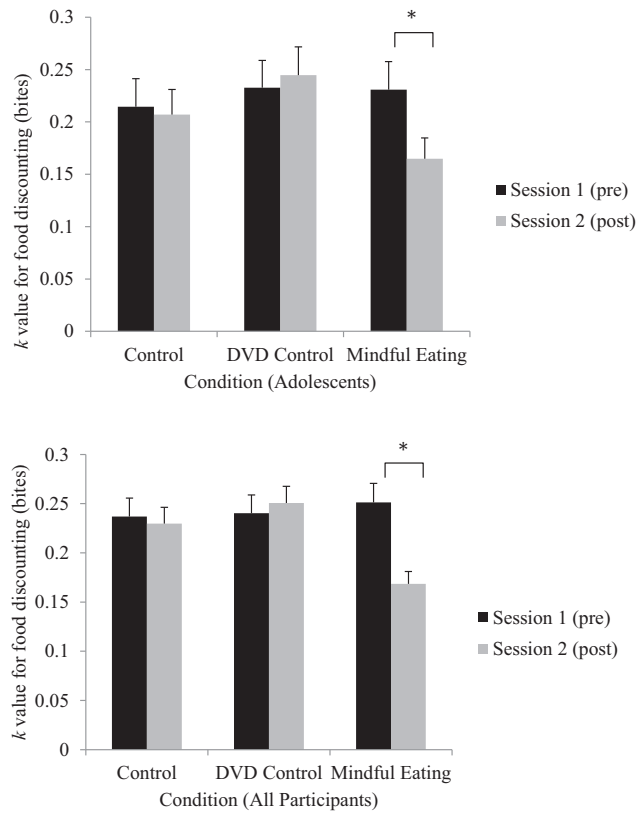

Figure 3. Mean *k* values (± SEM) food delay-discounting rates for Session 1 (premanipulation; black) and Session 2 (postmanipulation; gray) by condition for only adolescents (top; $n = 172$) and for all participants (bottom; $n = 348$, $^* p \leq .05$). DVD = group that watched a DVD.

For adolescent data, there was a statistically significant change in food discounting between conditions, $F(2, 169) = 3.50$, $p = .03$, $\eta_p^2 = .04$. For post hoc analyses, a paired sample *t* tests revealed that adolescents who participated in mindful-eating training significantly reduced their rate of discounting for food compared with baseline, $t(57) = 2.00$, $p = .05$, $d = 0.37$. Participants in the nutrition DVD and standard control groups did not exhibit change in their food discounting patterns (ps > 0.05). In addition, only adult data (not pictured) were analyzed and produced similar results such that there was a statistically significant change in food discounting between conditions, $F(2, 173) = 6.04$, $p = .03$, $\eta_p^2 = .07$. Adults who participated in the mindful-eating training evidenced more self-controlled food choices compared with baseline, $t(54) = 2.88$, $p = .006$, $d = 0.46$. Adults in the DVD and control conditions did not exhibit changes in food discounting (ps > 0.05). There were no main effects of condition, session, or an interaction for monetary discounting.

Results were similar when all participants, regardless of age, were included in the analyses. There was a statistically significant effect of condition on change in food discounting, $F(2, 345) = 9.37$, $p < .001$, $\eta_p^2 = .05$. The statistically significant effect held when time since last snack and time since last meal were controlled, $F(2, 316) = 7.97$, $p < .001$, $\eta_p^2 = 0.05$. A series of paired samples *t* tests showed that the difference between food $\log_{10}(k)$ in

the pre- and posttest was significant for those in the mindful-eating group, $t(111) = 3.03$, $p < .003$, $d = 0.38$. There were no significant changes in the control conditions (ps > 0.05). Excluding LOCF cases ($n = 24$), the test–retest reliability of the control group was statistically significant when Session 1 and Session 2 rates of food ($r = .51$, $p < .001$) and money ($r = .73$, $p < .001$) were correlated. Similarly, when age group (adolescent vs. adult) was added as a factor to control for potential differences between adolescent and adult change in discounting, the three-way interaction term (Session × Age Group × Condition) was not statistically significant ($p > .05$).

Discussion

Baseline Age and Delay Discounting

Adolescents demonstrated higher discounting rates for money than adults, suggesting that they are more sensitive to delays and prefer smaller, more immediate outcomes over larger, later outcomes. Furthermore, age predicted monetary discounting after accounting for associated variables. These findings are consistent with previous studies showing an inverse relation between age and delay-discounting rates in humans (e.g., Green et al., 1994; Green et al., 1996; Steinberg et al., 2009; Whelan & McHugh, 2009). A possible explanation for age-related changes in delay discounting is that adults have more experience with longer delays compared with children. Adults also have greater access to financial resources, which may impact their choice to wait for larger, later amounts of money. One study conducted in Israel, for example, demonstrated that adolescents who had greater access to money are more willing to wait for larger, later rewards (Lahav, Shavit, & Benzion, 2015). Developmental differences in the areas of the brain related to self-control, which is mature by age 20, could also account for these age-related differences (Diamond, 2002).

There were no developmental differences for food discounting between adolescents and adults. One interpretation of this is that food discounting rates are similar across age, at least between younger adolescents and college-age students. A longitudinal study that spans a wider range of ages would make a firmer conclusion. Another possibility is that pubertal maturation may make food discounting in adolescents similar to adults, as eating patterns shift after puberty (Nicklaus, Boggio, Chabanet, & Issanchou, 2004). Future research on food discounting processes with adolescents should use a measure of puberty to elucidate these processes.

Obesity and Delay Discounting

Monetary outcomes. Adults falling in the highest PBF quartile, who were obese, were more impulsive compared with those in the lowest PBF quartile, who were healthy-weight. This replicates other studies that found steeper discounting of with obese adult populations (e.g., Jarmolowicz et al., 2014; Weller et al., 2008). Adolescents falling in either the lowest or highest PBF quartile, however, discounted money similarly. Differences between age groups could be due to differences in PBF in relative frequencies reflected in the age group—the largest percentage of the lowest PBF quartile of the entire sample was made up of adolescent participants whereas the majority of highest PBF quartile comprised adults; this is not unusual given that PBF and fat mass increases with age in both males and females (Malina, 1996). In addition, there were a greater number of women, compared with men, in the highest PBF quartile for both adolescents and adults. Therefore, additional analyses compared the PBF effects within age range and controlled for gender effects.

Food outcomes. Individuals with high PBF discounted food more than individuals with low PBF, although this effect was more strongly seen in adults when PBF was used to predict delay-discounting patterns. This replicates previous work with college students and extends it to younger populations (Hendrickson & Rasmussen, 2013; Hendrickson et al., 2015; Rasmussen et al., 2010). This pattern was found after accounting for variables that might mitigate the relation between PBF, age, and food discounting.

Mindful Eating

In the current study, adolescents and adults who participated in the mindful-eating session were less sensitive to delays for food-related outcomes compared with baseline rates. There was no change in discounting patterns for any condition with regard to monetary outcomes, indicating that mindful-eating training affected food-related decisions and not choices for secondary reinforcers like money. These findings contribute to the literature on domain specificity, in which individuals with extensive experience with a health-related outcome often discount more steeply for that outcome compared with money. These stimulus-specific results also have been shown with opioid-dependent individuals and heroin (Madden et al., 1997; Odum, Madden, Badger, & Bickel, 2000), cigarette smokers and cigarettes (Bickel et al., 1999), alcoholics and alcohol (Petry, 2001), and consumers of erotic and sexual stimuli (Lawyer, 2008).

The mechanisms of change in mindful eating remain unclear; although, there are a number of possibilities (see Loucks et al., 2015). In the neurodevelopmental literature, executive functioning, which describes inhibitory control, planning, awareness, and attention, plays a role in discounting of delayed outcomes (Olson et al., 2007; Weatherly & Richard Ferraro, 2011) and eating styles contributing to the development of weight gain over the life span (Smith, Hay, Campbell, & Troller, 2011). Mindfulness has been shown to enhance executive functioning and working memory (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), likely facilitating a more self-controlled pattern of eating after training. Importantly, additional research is needed to confirm which components of mindfulness contribute to delay-discounting outcomes.

Last, it is important to point out the data from the control groups. Individuals who watched the educational video did not exhibit changes in discounting compared with their baselines in the food- or money-related tasks. We also included a third group that did not receive any treatment to compare to our other two groups, which not only added another control, but also supports test–retest reliability of discounting. Indeed, a number of studies show that money discounting is a relatively stable pattern of behavior across the life span (Anokhin, Golosheykin, & Mulligan, 2015; Lagorio & Madden, 2005; Odum, 2011). It appears that food discounting is also relatively stable across a span of at least 1 to 3 weeks.

These results add to other studies using mindfulness-based strategies for obese populations. Mindfulness has been shown to

reduce body mass and obesity-related stigma, as well as enhance quality of life (Alberts, Mulkens, Smeets, & Thewissen, 2010; Forman, Butryn, Hoffman, & Herbert, 2009; Lillis, Hayes, Bunting, & Masuda, 2009). Recently, Katterman, Kleinman, Hood, Nackers, and Corsica (2014) conducted a systematic review showing that mindfulness decreased binge eating and emotional eating when it served as a primary intervention. Most of these studies were conducted as treatment outcome studies with varying objectives and time frames. The present study was different in that it was laboratory based, such that more careful control of variables was accomplished. It demonstrated that mindful eating does indeed play a role in changing sensitivity to delay for food for adolescents and adults.

Limitations and Future Directions

There are limitations that should be addressed. First, the current study addressed one behavioral measure of impulsivity, namely delay discounting. Impulsivity is a complex construct that may be better understood with multiple behavioral measures, such as response inhibition, which can be measured with procedures such as the go no-go task (Fillmore, 2003). Second, although our body fat measure by bioelectrical impedance analysis (BIA) is a valid and noninvasive measure of body composition, there has been a reported trend for larger error in larger-mass obese individuals (Duren et al., 2008; Gray, Bray, Gemayel, & Kaplan, 1989). Body fat measurement may be improved by using a hydrostatic (underwater) method instead of BIA, although this is costly and time consuming. Third, it would also be advantageous for future delay-discounting studies involving youth and obesity to incorporate a measure of puberty as changes in hormones influence appetite and changes in energy expenditure (see King, Gibbons, & Martins, 2010). Fourth, this study was conducted with 12- to 15-year-old adolescents and college students, most of whom identified as Caucasian, and thus may not be generalizable to other age or cultural groups. Last, in terms of follow-up data, the current study demonstrated at least temporary changes in discounting patterns for food. It would be useful for researchers to determine how long lasting the effects of the 50-min mindful-eating strategy is and many mindful-eating training sessions are necessary to establish long-lasting results.

Conclusions

Using discounting as an outcome measure of eating behavior may shed light on possible intervention and prevention strategies for those with maladaptive behaviors, such as impulsive eating, which may lead to obesity over the life span. It also brings about questions regarding causality about impulsive food choice behavior—do individuals become overweight or obese because of discounting patterns of impulsive food choice or does being overweight or obese affect this pattern, or both? One answer may come from a recent study that found that the longer delay of gratification for food (i.e., more self-control) at the age of four was associated with a lower BMI 30 years later (Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013). This implies decision making for real food in early childhood is associated with weight problems later in life. Whatever the case may be, it appears that behavioral strategies that decrease an individual's sensitivity to delay may be advantageous to one's health over time.

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