# Differential Relations Between Delay Discounting and Distress Tolerance as a Function of Opportunity Cost and Alcohol Use

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Abstract

Delay discounting refers to one process by which an individual devalues delayed outcomes. Typical discounting tasks provide no information about events during delays to larger-later rewards. Imposing opportunity costs during the delay increases how steeply delayed rewards are discounted (Johnson, Herrmann, & Johnson, 2015). The present research evaluated if distress tolerance (i.e., one's ability to tolerate distressing emotions and events) is related to discounting rates when opportunity costs are low, high, or are left unspecified. In a sample of predominantly female college students, we partially replicated that delay discounting was related to distress tolerance when opportunity costs were unspecified (significant relations confined to particular facets of distress tolerance); but distress tolerance was not related to delay discounting when opportunity costs were specified as low or high. The nature of the relation between distress tolerance and discounting when opportunity costs were unspecified was clarified by a significant interaction between alcohol use and distress tolerance; distress tolerance was unrelated to delay discounting except among participants with problematic alcohol use. Further research is needed to characterize relations between alcohol use, distress tolerance, and delay discounting and inform prevention and treatment efforts in at-risk populations.

*Keywords:* opportunity cost, distress tolerance, delay discounting, impulsive choice, alcohol

## Public Significance

Individuals with problematic alcohol use who better tolerated distress were more likely to wait for delayed rewards, but only when opportunity costs associated with waiting were unspecified. Promoting distress tolerance may improve the ability to wait for delayed rewards in heavy-drinking populations, but may not influence the likelihood of waiting in non-drug-using populations or when waiting is associated with high opportunity costs.

# Differential Relations Between Delay Discounting and Distress Tolerance as a Function of Opportunity Cost and Alcohol Use

Every day, individuals face a plethora of choices, often between immediate gratifications and the promise of a better long-term outcome. Delayed outcomes are discounted in value in all species for which data are available (e.g., Mazur, 1987; Rachlin, Raineri, & Cross, 1991; Richards, Mitchell, de Wit, & Seiden, 1997; Woolverton & Anderson, 2006) but there appear to be both between- (e.g., Mazur, 2000) and within-species (Odum, 2011) differences in the rate at which delayed rewards are discounted. Among humans, excessive discounting is associated with a variety of poor health and social outcomes (see Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012 for review).

Usually, steepness of discounting is determined in humans by asking individuals to choose between hypothetical smaller-immediate and larger-delayed reward pairs across a range of delays. What happens during the delay is unspecified, leaving it to participants to imagine a continuum of interpretations. At one extreme, they might assume their activities are limited until the delay elapses. Such high opportunity-cost delays resemble those arranged in nonhuman animal research on delay discounting. Paglieri (2013) referred to these as “waiting” delays. At the other extreme, participants would assume no opportunity costs are imposed during the delay; i.e., they are free to go about their lives as normal. Paglieri referred to these as “postponing” delays.

Nearly all research examining group differences, correlates, and manipulations of delay discounting in humans has been performed using tasks in which the opportunity costs during the delays are unspecified. In one exception to this rule, Johnson, Herrmann, and Johnson (2015) manipulated levels of opportunity cost imposed during the larger-later reward delay. As expected, rates of delay discounting increased as opportunity costs increased.

Further exploration of delay discounting under high and low opportunity costs appears warranted. High opportunity cost delays may be more relevant to disorders characterized by addiction because the delay to the long-term benefits of abstinence necessarily entails opportunity costs (e.g., no drug intake, avoiding drug-using friends). Therefore, discounting under specified opportunity-cost conditions might be a more robust predictor of relapse, treatment response, and long-term outcomes. Ultimately, a better understanding of the variables that relate to, and potentially moderate the effects of opportunity costs on delay discounting could prove useful in the treatment of addictive disorders.

One process that may be relevant in predicting delay discounting with high opportunity-cost delays is distress tolerance. Distress tolerance refers to an individual's ability to tolerate distressing events (Simons & Gaher, 2005) or to persist in a task despite experiencing distress (Daughters, Lejuez, Bornovalova, et al., 2005). Waiting delays may be distressing if they entail significant opportunity costs, such as having to wait alone in a room, with nothing to do but think (Wilson et al., 2014). As a result, individuals who poorly tolerate distressing events may steeply discount the value of rewards obtained following high opportunity-cost waiting delays.

Behaviorally measured psychological distress tolerance is related to treatment outcomes and behaviors related to substance use. For instance, individuals with low levels of distress tolerance exhibit shorter durations of smoking abstinence (Brown, Lejuez, Kahler, Strong, & Zvolensky, 2005; Daughters, Lejuez, Kahler, Strong, & Brown, 2005), and tend to drop out of substance abuse treatment early (Daughters, Lejuez, Bornovalova, et al., 2005; MacPherson, Stipelman, Duplinsky, Brown, & Lejuez, 2008). Likewise, self-reported distress tolerance is related to self-reported substance-use frequency and/or duration of drug use and self-reported problems associated with drug use (e.g., Buckner, Keough, & Schmidt, 2007; Howell, Leyro, Hogan, Buckner, & Zvolensky, 2010).

Only one study has examined the relation between distress tolerance and delay discounting. Dennhardt and Murphy (2011) found that distress-intolerant individuals more steeply discounted delayed rewards. Two limitations of their study are addressed in the present experiment. First, Dennhardt and Murphy used a discounting procedure that leaves the events during the delay unspecified (Kirby, Petry, & Bickel, 1999). Thus, the relation between distress tolerance and discounting as measured in tasks specifying opportunity costs has yet to be studied. Second, their sample consisted solely of heavy-drinking college students. In a pilot study conducted in our lab with predominantly non-drinking college students, delay discounting rates were not correlated with levels of distress tolerance. The present research was conducted with a more heterogeneous sample of college students to test the possibility that alcohol use moderates this relation. In addition, for the first time, the relation between distress tolerance and discounting was explored with tasks arranging high and low opportunity cost delays. Because high opportunity-cost delays are anticipated to be more distressing than those arranged in the typical delay-discounting task, we hypothesized that the relation between distress tolerance and discounting rates would be stronger when opportunity costs are imposed.

## Method

### Participants

Undergraduate students enrolled in psychology coursework were given the opportunity to complete an online demographics screening questionnaire (Qualtrics, Inc.; Provo, UT) hosted on the departmental recruitment website (Sona Systems, Ltd.; Tallinn, Estonia). Individuals 18 years of age or older were eligible to participate. Seventy-eight students participated in sessions scheduled between 10 am and 5 pm, Monday through Thursday. All participants provided informed consent and received course credit for participating. All procedures were approved by the Institutional Review Board of California State University, Chico.

## Materials

Participants completed all measures in electronic format. They first completed a demographic survey (age, sex, race, ethnicity, religious affiliation, religiosity [Plante & Boccaccini, 1997], years of education, available/expendable money [as proxies for income]) and a drug use questionnaire. For the latter, participants indicated past-year use of 19 different drugs (e.g., alcohol, amphetamines, inhalants, MDMA, etc.). Positive responses were followed-up with questions about more recent use (i.e., past-month and week use as applicable). For drugs used in the past year, participants completed a checklist containing the 11 DSM-5 criteria for substance use disorders (American Psychiatric Association, 2013). Additional questionnaires were completed but not subjected to analyses; these data are not reported here.

**Standard Delay Discounting Task.** The standard delay-discounting task (DD-ST) used a titrating-amount procedure to obtain indifference points (Du, Green, & Myerson, 2002). Participants were instructed to choose between smaller-sooner and larger-later hypothetical monetary rewards. Full instructions for this and the other discounting tasks are provided in Appendix A. The first choice was between $500 now and $1,000 in 1 week. Participants indicated their selection by clicking a button below the preferred option. If the immediate (delayed) reward was chosen, then on the next trial the amount of the immediate reward was decreased (increased) by 50% (i.e., $250). This process was repeated for 8 trials, with the adjustment amount decreasing by 50% in each successive trial (i.e., $125 on the second trial,

$62.50 on the third trial, and so on). The indifference point was taken as the smaller-immediate amount that would have been displayed on the ninth trial had it been presented. Seven blocks of trials were completed in this manner with increasing delays to the $1,000 reward: 1 week, 2 weeks, 1 month, 6 months, 1 year, 5 years, and 25 years.

**Opportunity Cost Delay Discounting Tasks.** Two opportunity-cost delay discounting tasks were arranged (see Johnson et al., 2015). In one, the delays imposed minimal opportunity costs (DD-MIN); i.e., participants were instructed that they would be free to go about their typical life while the delay to the $1,000 reward elapsed. In the other (DD-MAX), participants were instructed that they had to stay in the lab for the duration of the delay, with little ability to engage in activities to entertain oneself. After reading the instructions, participants were required to pass a three-item quiz (see Appendix A). The instructions and quiz were repeated until all items were answered correctly. The assessment of discounting in the DD-MAX and DD-MIN tasks was identical to the DD-ST task with the following exceptions: the larger-later reward was $10, and indifference points were assessed across delays of 5 minutes, 10 minutes, 30 minutes, 1 hour, 3 hours, 6 hours, 12 hours, and 24 hours.

**Distress Tolerance Scale.** Because behavioral and self-reported forms of distress tolerance do not correlate (McHugh et al., 2011), participants completed both a self-report and behavioral measure of distress tolerance. The Distress Tolerance Scale (DTS) is a 15-item self-report measure of distress tolerance that contains 4 first-order factors corresponding to different aspects of distress tolerance (Simons & Gaher, 2005). The four factors are tolerance (ability to tolerate distress), appraisal (subjective view of whether it is acceptable/appropriate to be distressed), regulation (how much an individual engages in behaviors to avoid distress), and absorption (how consumed an individual becomes by distress). Each item on the DTS (e.g., "Feeling distressed or upset is unbearable to me") prompts participants to rate their agreement with the statement using a 5-point Likert scale (1 = "Strongly Agree" and 5 = "Strongly Disagree"). The total DTS score is the average rating on each of the four subscales, and the subscale scores are the average score of the items comprising that factor. Higher scores indicate a greater tolerance of emotional distress. The DTS total scale has good internal consistency ($\alpha$ = .82 to .89; Simons & Gaher, 2005).

Of primary interest were the total scale and regulation subscale scores. Only these scores were included in analyses due to their theoretical relevance to discounting, with the DTS-total representing overall ability to tolerate distress, and the DTS-regulation subscale representing behavioral manifestations of distress tolerance.

**Paced Auditory Serial Addition Task - Computerized (PASAT-C).** The PASAT-C is a behavioral measure of psychological distress tolerance (Lejuez, Kahler, & Brown, 2003) in which participants must add consecutive numbers displayed on a computer screen. Correct sums increment a point counter by one and incorrect responses and omissions (failure to respond before the next digit appeared) initiate an explosion sound but do not affect points.

The PASAT-C contained three phases. The first was a 2-minute practice phase in which the interval between numbers adjusted depending on participant accuracy (shorter when answering correctly, and longer when incorrect). The second phase consisted of two blocks in which the interval between numbers was 75% of the average adjusted interval in the first block (1-minute duration) and 50% of this average in the second block (2-minute duration). The third phase was identical to the second block of the second phase but participants could terminate the task by pressing a "Quit Task" button. If this button was not pressed, the task terminated after 7 min. Engaging with the PASAT-C increases self-reported levels of distress (Bornovalova et al., 2008; Daughters, Lejuez, Bornovalova, et al., 2005; Daughters, Lejuez, Kahler, et al., 2005) and, therefore, the duration of persisting in the third phase represents distress tolerance.

The PASAT-C includes a pre- and post-assessment of distress as a manipulation check. In these assessments, participants rate to what degree they feel “anxiety,” “physical discomfort,” “frustration,” “irritability,” “happiness,” and “difficulty concentrating”. Participants indicated their response, on a scale of 0 (none) to 100 (extreme), using a slider tool on a visual analogue scale below each emotional descriptor.

**Procedure**

Participants completed demographic and drug use questionnaires and the DD-ST in that order. The DD-MAX and DD-MIN were completed in counterbalanced sequence across participants (random assignment). The DTS and the PASAT-C were then completed in this order; the DTS was completed before the PASAT-C to avoid any potential carryover effects of distress induced by the PASAT-C. Sessions lasted 30-60 minutes.

**Data Analysis**

Prior to conducting statistical tests, several screening procedures were conducted. First, all discounting data sets were screened for non-systematic data according to the two criteria (non-monotonic decrease in subjective value and non-discounting) outlined by Johnson and Bickel (2008). Excluding nonsystematic data is appropriate because such data yield discounting rates (and AUC values) of questionable validity (see Johnson & Bickel, 2008 for discussion). Because non-discounting is plausible across the brief range of delays and minimal opportunity costs in the DD-MIN task, participant data were excluded on this task only if they were classified as non-monotonic (see Johnson, Herrmann, & Johnson, 2015).

To ensure these exclusions did not affect the conclusions reached, discounting analyses were also conducted with nonsystematic data included. Results were similar in statistical significance and effect size. Therefore, only those analyses conducted with valid discounting data are reported herein. All analyses were conducted using *R* (R Core Team, 2013) with the exception of model fits which were conducted using GraphPad Prism version 7.0 (GraphPad Software Inc., La Jolla, CA).

Data were assessed for univariate and bivariate normality and outliers as appropriate. Univariate normality was assessed using the Shapiro-Wilks goodness-of-fit test, and outliers were defined as data points beyond 3 times the interquartile range (IQR). Bivariate normality was assessed via visual inspection of scatterplots and/or residuals. When the assumption(s) of normality were violated, nonparametric statistical tests were used.

In addition to the above screening procedures, the pre- and post- affective data from the PASAT-C were examined to ensure the task increased distress. A composite negative-affect change score (i.e., change in anxiety, discomfort, frustration, and irritation) was compared to 0 using a Wilcoxon signed-rank test. PASAT-C persistence scores were the task persistence time in the final phase divided by maximum phase duration (7 minutes).

Problematic drug use was quantified using the DSM-5 checklist. Participants reporting no use of a particular drug in the last year were scored “0”. Scores for all others were 1 (past year use) plus the number of DSM-5 criteria endorsed for that drug. Scores of 3-4, 5-6, and 7-8 are indicative of mild, moderate, or severe substance use disorders, respectively.

***Discounting analyses.*** For purposes of graphic presentation, the hyperbolic discounting function (Mazur, 1987) was fit to the median indifference points across participants from each of the discounting tasks:

$$V = \frac{A}{1+kD} \quad (2)$$

where $V$ is the present value of the larger delayed reward (i.e., the indifference point), $A$ is the undiscounted amount of the larger delayed reward ($10 or $1000, depending on the task), $D$ is the delay, and $k$ is a free parameter that reflects the rate at which the larger, delayed reward loses its value as a function of delay. Goodness of fit was evaluated using the root mean squared error (RMSE), which reflects the standard deviation of the residuals (error) for the fitted function. Area under the curve (AUC) was used to quantify degree of discounting. AUC is an atheoretical measure of discounting that is derived by summing the area of each trapezoid formed by two adjacent indifference points (see Myerson, Green, & Warusawitharana, 2001). Values range from 0 to 1, with lower values reflecting greater discounting.

To examine if the opportunity cost manipulation significantly changed discounting across DD-MIN and -MAX assessments, AUC values were compared using a Wilcoxon signed-rank test. A nonparametric test was chosen due to the high degree of skewness and inability to transform AUC values from the DD-MIN task to normality. For this analysis, only individuals who provided systematic data on both the DD-MIN and DD-MAX were included. In addition, the effect of order on discounting in the opportunity cost tasks was examined using two Wilcoxon signed-rank tests (once each with AUCs from the DD-MIN and -MAX tasks as the dependent variable). All *p*-values pertaining to comparisons of discounting across opportunity cost conditions and the effects of order were corrected for multiple comparisons using the False Discovery Rate method (Benjamini & Hochberg, 1995).

***Relations between demographics, steepness of discounting, and distress tolerance.*** The relations between discounting in each of the three DD tasks, distress tolerance, and drug use measures were examined using Pearson, Spearman, and point-biserial correlations as appropriate. Spearman correlations were used for correlations involving the following variables, due to their high degree of skewness and bivariate non-normality not corrected by transformations: AUC in the DD-MIN and DD-MAX tasks, PASAT-C persistence scores, and alcohol and cannabis DSM-5 scores. Additionally, all correlations involving tobacco use (dichotomous: any past-year use vs. no past-year use) were point-biserial correlations on the rank-transformed values; prevalence and degree of tobacco use was very low in this sample, which precluded the use of a continuous measure for tobacco use. Because the number of discounting datasets excluded as nonsystematic varied across tasks, samples sizes varied across correlations. An alpha correction was not applied to correlational analyses because doing so at this exploratory stage hinders the identification of potentially important relations that may be examined further in future research.

Following correlational analyses, generalized linear modeling (GzLM) was conducted to clarify the relation between distress tolerance and steepness of discounting. GzLM was chosen for its ability to accommodate a proportional dependent variable (AUC), which was achieved by specifying a beta-error distribution and using a logit-link function (i.e., a beta regression). Because distress tolerance was not significantly related to delay discounting in the DD-ST task (as had been reported among heavy-drinking college students by Dennhardt & Murphy, 2011), alcohol use was explored as a moderator influencing the relation between distress tolerance and steepness of discounting. For this analysis, a GzLM was constructed with steepness of DD (AUC) from the DD-ST task as the dependent variable, and total DTS score, alcohol DSM-5 score, and their interaction as independent variables. Model significance was evaluated using Wald Chi-squared tests, comparing the above model to the null model. Only participants who provided systematic data on the DD-ST and fully completed the DTS were included in this analysis ($n$ = 58). Assumptions of the GzLM were verified by examining residuals and screening for overly-influential observations (quantified by computing Cook's *D* and using a cut-off value of 4/*n*, or 0.07, for identification).

**Results**

A total of 78 participants enrolled in the study. One participant did not complete all tasks due to a survey error and another provided nonsystematic data on all three DD tasks; data from these participants were excluded from all analyses ($N$ = 76). All other participants completed the entirety of the session, with the exception of 1 participant who was unable to complete the PASAT-C due to a power outage; this participants' data were retained in all analyses except those involving the PASAT-C. Assignment to the opportunity-cost discounting task sequences was similar, with slightly fewer participants receiving the DD-MIN first ($n$ = 34).

Demographic characteristics are shown in Table 1. Participants were predominantly female (85.5%), with a median age of 22 years (range 18-54). Most participants identified their race as white (65.8%) and ethnicity as non-Hispanic/Latino (59.2%). Table 2 shows the number of participants at each DSM-5 score for alcohol, cannabis, and alcohol and cannabis combined. Within the sample, 47.4% ($n$ = 36) and 32.9% ($n$=25) had DSM-5 scores of 3 or greater (moderate use) for alcohol and cannabis, respectively. Tobacco use was infrequent; the median DSM-5 score for tobacco was 0 (as was the IQR).

Demographic and individual difference variables were largely unrelated to the primary measures of interest. Age was not related to steepness of discounting in any of the tasks ($\rho$s $\leq$ .19, $p$s $\geq$ .16), nor was expendable or available income ($\rho s \leq$ .15, $p$s $\geq$ .23). Age was, however, significantly correlated with distress tolerance and drug-related measures: older participants reported greater distress tolerance (DTS-Total scores, $\rho$ = .29, $p$ = .01) and lower DSM-5 scores for alcohol ($\rho$ = -.23, $p$ = .04). Composite scores of negative affect prior to completing the PASAT-C were significantly related to overall psychological distress tolerance: there was a significant, negative relation between DTS-total scores and negative affect, $\rho$ = -.36, $p$ = .002. However, negative affect was not significantly related to any of the discounting measures (all *p*s $\geq$ .38).

**Data Validity**

After applying the Johnson and Bickel (2008) exclusion criteria for nonsystematic data, there were a total of 42 valid sets of DD data across all three tasks and 50 valid sets of DD data across the two opportunity cost tasks. Across the DD-ST, DD-MIN, and DD-MAX tasks, 17 (22%), 19 (25%), and 7 (9%) participants' data were classified as nonsystematic. These percentages of non-systematic data are typical of the literature (see meta-analysis by Smith, Lawyer, & Swift, in press).

Completion of the PASAT-C increased levels of distress. Based on the composite change score of distress-related affect, 70 participants reported increased distress, 1 reported no change, and 4 reported a nominal decrease in distress following the PASAT-C. The results of the Wilcoxon signed-rank test confirmed the increase in distress was significantly greater than zero ($V$ = 2735, $p$ < .0001).

**Steepness of Discounting**

As shown in Figure 1, the median indifference points from the DD-ST were well described by the hyperbolic equation (RMSE = 61.12 and $R^2$ = 0.97; RMSE with subjective values scaled to that in the opportunity cost tasks is .63). The median AUC in the DD-ST task was 0.32 (Q1 = .09, Q3 = .48).

As shown in Figure 2, median indifference points from the opportunity-cost discounting tasks were generally well described by the hyperbolic equation in both DD-MIN (RMSE = 0.06; $R^2 = 1.00$) and DD-MAX (RMSE = 1.52, $R^2 = 0.90$), although predicted indifference points are systematically higher than observed data at mid- to longer-range delays in the DD-MAX task. The degree of discounting in DD-MAX (*Mdn* AUC = .09) was much higher than that in DD-MIN (*Mdn* AUC = .99), $V = 1270$, $p < .0001$, indicating that opportunity costs increased rate of delay discounting. There was no significant effect of order on degree of discounting in the DD-MIN and -MAX tasks (*p*s $\geq$ .22).

**Relations Between Drug Use, Steepness of Discounting, and Distress Tolerance**

Correlations between distress tolerance measures, steepness of discounting on the three delay discounting tasks, and alcohol and cannabis use are presented in Table 3. Cannabis, but not alcohol use was significantly correlated with discounting in the DD-MAX task (see Figure 3): lower AUC values (greater discounting) were associated with more, and more problematic cannabis use ($\rho = -.31$, $p = .009$). This correlation remained significant when removing three outliers (> 3 times the IQR; $\rho = -.28$, $p = .03$) and when excluding seven participants with DSM-5 scores for tobacco of 3 or higher (to rule out nicotine use as confounding variable; $\rho = -.33$, $p = .008$). No other correlations between discounting measures and drug use were significant.

Steepness of delay discounting in the DD-ST and DD-MAX were significantly correlated ($\rho = .32$, $p = .02$). Individuals with higher AUC in the DD-ST tended to have higher AUC in the DD-MAX. Steepness of discounting in the DD-ST and DD-MIN was not significantly related ($\rho = .21$, $p = .17$). The DTS-total score and the DTS-regulation subscale scores were strongly correlated ($r = .72$, $p < .001$), but neither was correlated with PASAT-C measures ($\rho$s $\leq$ .13, *p*s $\geq$ .28).

Of the distress tolerance measures, only a particular facet of emotional distress tolerance (DTS) was related to steepness of discounting, and only on the DD-ST task. As shown in the left panel of Figure 4, scores on the DTS-regulation subscale were significantly related to steepness of discounting ($r$ = .29, $p$ =.03); in other words, greater engagement in distress-reducing behaviors was associated with steeper discounting in the standard discounting task. Total DTS scores, however, were not significantly related to steepness of discounting in this task, ($r$ = .23, $p$ = .08; see Fig. 4). Neither persistence times on the PASAT-C nor the extent to which the PASAT-C increased distress were related to steepness of discounting on any of the tasks ($\rho$s and $r$s $\leq$ .10, $p$s $\geq$ .44).

The results of the GzLM supported the hypothesis that alcohol use moderates the relation between distress tolerance and steepness of discounting on the DD-ST. Four overly influential observations were identified (Cook's $d \geq$ .10) and excluded from analysis. The GzLM was significant, $\chi^2(3) = 8.58$, $p$ = .04, as was the interaction between distress tolerance and alcohol checklist score ($p$ = .04). The results of the analysis are shown in Table 4, which demonstrate that only the interaction between distress tolerance and alcohol use is significant; no significant bivariate relation between DTS scores and discounting was found. Notably, the model was functionally significant regardless of the inclusion of the overly influential observations ($p$ = .051), and the weights of predictors were similar. Including tobacco use and negative affect (pre-completion of the PASAT-C) did not improve the model ($p$s = .30 and .64, respectively); neither variable predicted AUC ($p$s = .30 and .64).

To clarify the nature of the interaction between distress tolerance and problematic alcohol use, Figure 5 shows model predictions of AUC on the DD-ST as a function of varying levels of distress tolerance for low, moderate, and high levels of problematic alcohol use (DSM-5 scores of 1, 4, and 7, respectively). Overall, in the absence of problematic alcohol consumption, there was no relation between distress tolerance and steepness of delay discounting (dotted line). However, as problematic alcohol use increased, better distress tolerance (i.e., higher DTS-total scores) was increasingly related to less discounting of delayed rewards (i.e., higher AUCs). Note that predictions at the high level of problematic alcohol use are included for illustrative purposes; the estimated model parameters are primarily based on low to moderate scores ($n$ = 16 and 13, respectively) with six participants' problematic use at or between scores of 5 and 8.

Lastly, in an exploratory effort to determine if the lack of bivariate relation between discounting in the DD-MAX and distress tolerance was due to interactions with alcohol use (as in Figure 5), the above analyses were repeated using DD-MAX AUC as the dependent variable. This model was not significant.

## Discussion

The results of the present experiment suggest, contrary to expectation, that distress tolerance—whether measured behaviorally or by self-report—is not related to delay discounting when minimal (DD-MIN) or maximal (DD-MAX) opportunity costs are specified to occur during large-reward delays. That is, there were no significant relations between DTS and PASAT-C scores and steepness of delay discounting on the aforementioned discounting tasks. However, steepness of discounting in the standard task (DD-ST) was significantly related to a particular facet of self-reported distress tolerance (how one behaviorally regulates their distress). By contrast, Dennhardt and Murphy (2011) found that *overall* DTS scores were related to steepness of discounting in a sample of heavy drinking college students (they did not report relations with subscale scores). Our failure to replicate with a sample more heterogeneous on drug use can be explained by the significant interaction between DTS-total scores and DSM-5 scores for alcohol: overall distress tolerance was only related to discounting among those evidencing more problematic alcohol use. To the extent that steep delay discounting precedes and predicts alcohol use (e.g., Fernie et al., 2013; Khurana et al., 2014), therapeutic efforts to reduce misuse might profitably target improvements in distress tolerance. Improved willingness to experience distressing events, and developing a less reactive relation to these events, is a target of contemporary mindfulness-based interventions shown to reduce substance use and long-term relapse (e.g., Bowen et al., 2014).

A second novel finding in the present report is that more problematic cannabis use was positively correlated with steep delay discounting in the DD-MAX task; i.e., the task in which participants were informed that, hypothetically, waiting for the larger-later reward required staying in the laboratory, alone, with nothing to do until the delay elapsed. Cannabis use was not correlated with discounting in the DD-ST task, a finding consistent with most other published studies (M. W. Johnson et al., 2010; Kollins, 2003). Interestingly, the correlation between cannabis use and DD-MAX AUC remained significant after outliers on the DD-MAX task were removed and participants with high DSM-5 scores for tobacco were excluded from the analysis. However, it is worth noting that there were few participants with moderate and high DSM-5 scores for cannabis. Future research should aim to replicate this finding in a sample displaying greater heterogeneity in cannabis use.

The extent to which high and low opportunity cost delay-discounting tasks tap into distinct decision-making processes—both of which may be involved in addictive behavior—should remain a focus of future research. For example, low opportunity-cost delay discounting might be expected to better predict initiation of drug use (e.g., Audrain-McGovern et al., 2009) because no opportunity costs are paid while waiting for the negative effects of drug use to accrue (e.g., reduced health, wealth, and family bonds). By contrast, high opportunity-cost delay discounting might be expected to better predict failure in substance-abuse treatment trials because significant opportunity costs are paid while waiting for improvements in daily life.

Distress tolerance, while relevant in certain circumstances to steepness of discounting (i.e., in typical, implicitly low-opportunity cost discounting tasks such as the DD-ST), does not appear to play a role in discounting when one is required to wait in an impoverished environment (DD-MAX). Thus, high opportunity-cost delay discounting is a different decision process with different determinants. As such, existing methods for reducing delay discounting with low (or implicitly so) opportunity costs, such as episodic future thinking (e.g., Stein et al., 2016) or reframing (e.g., Read, Frederick, Orsel, & Rahman, 2005), may not reduce delay discounting when waiting involves significant opportunity costs. If future studies replicate the finding that waiting-delay discounting is related to problematic cannabis use, or to problematic use of other illicit drugs not evaluated here, this may prove important in developing interventions designed to reduce delay discounting and addictive behavior.

Although problematic drug use has been reliably linked to steep delay discounting (MacKillop et al., 2011), relations between self-reported drug-use and discounting on the standard task (DD-ST) were not significant in the present study. These results may be due to the fact that effect sizes for associations between discounting and severity of drug use are smaller than those typically found in comparisons of clinical populations to -non (Amlung, Vedelago, Acker, Balodis, & MacKillop, 2017); and thus the size of our relatively sub-clinical sample may not have been large enough to detect these particular associations. Finally, because problematic drug use is highly comorbid with other psychiatric conditions (Grant et al., 2015), our sample probably differed in other ways that impacted discounting (e.g., higher education).

## Limitations and Future Directions

One limitation of the present study is the PASAT-C may not have provided a valid behavioral assessment of psychological distress tolerance. Although self-reported distress from pre- to post-task increased, nearly half of the participants ($n$ = 36) continued through the task until it automatically terminated. Thus, the primary dependent measure of the PASAT-C may have provided insufficient variability to detect relations between behavioral distress tolerance and other dependent measures such as delay discounting. Alternatively, behavioral measures of psychological distress tolerance such as the PASAT-C tend to significantly correlate with *behavioral* outcomes (e.g., dropout from treatment; MacPherson et al., 2008) but not self-reported behaviors (e.g., motivations for drug use). Future studies should explore the relation between persistence in the PASAT-C and degree of opportunity-cost delay discounting when *real* rewards and delays are arranged.

The demographic characteristics of the sample (more educated, predominantly female, young adults enrolled in coursework in psychology) are a limitation of this study. Scores on the DTS are predictive of alcohol problems in men but not women (Simons & Gaher, 2005) and the mostly female sample herein may have contributed to the lack of a significant bivariate relation between problematic alcohol use and overall distress tolerance. Scores on the DTS are also related to coping motives for substance use (i.e., to alleviate negative affect; Simons & Gaher, 2005), which tends to be a more common reason for alcohol use among men (Gire, 2002; Rutledge & Sher, 2001). Regardless of gender differences, coping motives for alcohol use are associated with greater alcohol-related problems and dependence (LaBrie, Ehret, Hummer, & Prenovost, 2012; Lyvers, Hasking, Hani, Rhodes, & Trew, 2010) and the more gender-diverse sample of Dennhardt and Murphy (2011) revealed similar associations between discounting and distress tolerance as those reported herein. Thus, it is possible that the utility of our results is more limited to individuals with specific patterns of use, rather than to those of specific genders. Future research that expands upon this exploratory project should aim to recruit a more diverse sample, or a sample of problem drug-users to further define the relations between distress tolerance, discounting, and substance use as a function of such individual differences.

Last, future research should include measures of both state- and trait-based levels of negative affect in examining relations between discounting and distress tolerance. While state-based negative affect was related to distress tolerance on the DTS, it was not related to discounting in correlational or regression analyses. The possibility remains then, that the associations between distress tolerance, alcohol use, and discounting were due to a broader, trait-like tendency to experience negative affect rather than distress tolerance per se. The plausibility of this alternative explanation is difficult to ascertain because there is inconsistency in whether trait-based negative affect (e.g., level of depression) is related to discounting, with findings pointing toward both significant (Yoon et al., 2007) and non-significant relations (Dennhardt & Murphy, 2011). It would appear that if trait-level negative affect accounts for any of the shared variance between discounting and distress tolerance, that it may be the product of interactive relations as was studied herein. Unfortunately, few such studies exist (see Hirsh, Guindon, Morisano, & Peterson, 2010 for one example) and future research will need to focus on identifying individual-difference variables that further moderate the associations between clinically-relevant constructs and behaviors.

**Summary and Conclusions**

While our results suggest distress tolerance is not related to discounting with high opportunity costs, our findings may have clinical and practical implications. First, distress tolerance was related to delay discounting with implicitly low opportunity costs, but only among those higher in alcohol dependence. This finding suggests alcohol-dependent individuals may benefit from interventions designed to improve distress tolerance. Second, delay discounting with high opportunity costs was found to be significantly related to cannabis use. Whether individuals who are more sensitive to opportunity-cost delays are more likely to use cannabis, or vice versa, consideration of opportunity costs in the prevention and treatment of cannabis use disorders may prove valuable.

In sum, the present findings demonstrate that opportunity costs not only affect degree of discounting, but also the relevant processes that may dictate decision-making. Thus far, discounting across different levels of opportunity costs appears independent, and future research will need to further explore how decision-making in these contexts differentially relates to addiction-related outcomes and their treatment.

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Table 1.

*Percentages and counts, or medians and 1st and 3rd quartiles, for categorical vs. continuous demographic measures for the study sample (N = 76).*

| | % (*n*) | Median | Q1-Q3 |
|---|---|---|---|
| Age (years) | | 22 | 21-25 |
| Sex | | | |
| Male | 13.16% (10) | | |
| Female | 85.53% (65) | | |
| N/A | 1.32% (1) | | |
| Race | | | |
| African American/Black | 3.95% (3) | | |
| Hawaiian/Pacific Islander | 2.63% (2) | | |
| White | 65.79% (50) | | |
| N/A | 27.63% (21) | | |
| Ethnicity | | | |
| Non-Hispanic/Latino | 59.21% (45) | | |
| Hispanic/Latino | 38.16% (29) | | |
| N/A | 2.63% (2) | | |
| Expendable Income | | 125.00 | 50.00-500.00 |
| Available Income | | 1400.00 | 387.50-3500.00 |
| Alcohol Use | | | |
| >1 year or never | 9.21% (7) | | |
| Past year | 15.79% (12) | | |
| Past month | 31.58% (24) | | |
| Past week | 43.42% (33) | | |
| Alcohol DSM Score | | 2 | 1-4 |
| Cannabis Use | | | |
| >1 year or never | 43.42% (33) | | |
| Past year | 18.42% (14) | | |
| Past month | 14.47% (11) | | |
| Past week | 23.68% (18) | | |
| Cannabis DSM Score | | 1 | 0-3 |
| Tobacco Use | | | |
| >1 year or never | 76.32% (58) | | |
| Past year | 11.84% (9) | | |
| Past month | 6.58% (5) | | |
| Past week | 5.26% (4) | | |
| Tobacco DSM Score | | 0 | 0-0 |

Note: Percentages for demographic variables do not always sum to 100% due to rounding. Alcohol, Cannabis, and Tobacco DSM Scores refer to the DSM-5 checklist scores for substance use disorder; scores are the number of items endorsed (out of a total of 11) for the checklist pertaining to that substance plus one (i.e., those not consuming alcohol in the past year have a score of “0”, those who checked no items but reported consuming alcohol have a score of “1”, etc.)

Table 2.

*Number (and percentage) of participants meeting criteria for different levels of substance use for the study sample (N = 76). Score ranges reflect the DSM-5 scores.*

| DSM-5 Substance Use Classification | *n* (%) |
|---|---|
| Alcohol | |
| <=2 | 40 (52.63%) |
| Mild (3-4) | 26 (34.21%) |
| Moderate (5-6) | 6 (7.89%) |
| Severe (7+) | 4 (5.26%) |
| Cannabis | |
| <=2 | 51 (67.11%) |
| Mild (3-4) | 13 (17.11%) |
| Moderate (5-6) | 5 (6.58%) |
| Severe (7+) | 7 (9.21%) |
| Alcohol + Cannabis | |
| Both <= 2 | 31 (40.79%) |
| One at least mild (≥ 3) | 29 (38.16%) |
| Both at least mild (≥ 3) | 13 (17.11%) |
| Both at least moderate (≥ 5) | 3 (3.95%) |
| Both at least severe ( ≥ 7) | 0 (0.00%) |

Table 3.

*Correlations between steepness of discounting, distress tolerance, and drug use measures.*

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. ST-AUC | | *44* | *57* | *58* | *58* | *58* | *58* | *59* | *59* | *59* |
| 2. Min-AUC | .21 | | *50* | *56* | *56* | *56* | *56* | *57* | *57* | *57* |
| 3. Max-AUC | .32* | .24 | | *68* | *68* | *68* | *68* | *69* | *69* | *69* |
| 4. DTS-total | **.23** | .04 | -.01 | | *75* | *75* | *75* | *75* | *75* | *75* |
| 5. DTS-regulation | **.29*** | .20 | <.01 | **.72***** | | *75* | *75* | *75* | *75* | *75* |
| 6. PASAT-C Distress | **-.09** | .02 | .10 | **-.07** | <.01 | | *75* | *75* | *75* | *75* |
| 7. PASAT-C Duration | .10 | .05 | -.02 | .11 | .13 | -.06 | | *75* | *75* | *75* |
| 8. Alcohol DSM | **.12** | .15 | -.13 | **-.07** | **.02** | **.00** | .18 | | *76* | *76* |
| 9. Cannabis DSM | -.07 | -.09 | -.31** | .04 | .06 | -.02 | -.19 | .24* | | *76* |
| 10. Tobacco Use[#] | -.19 | .05 | .07 | -.14 | <.01 | .20 | -.27* | .39*** | .19 | |

* $p < .05$, ** $p < .01$, *** $p < .001$

[#] All correlations involving tobacco use (past-year use vs. none) are point-biserial correlations.

Note: Sample sizes are shown above the diagonal in italics, and correlation coefficients are shown below. Bolded coefficients are Pearson's *r*, and unbolded are Spearman's $\rho$.

Table 4.

*Parameter Estimates from the Generalized Linear Model Analysis of the Interaction Between Self-Reported Distress Tolerance and Alcohol Use*

| Variable | *Beta (Std Error)* | *Z* | *p* | $\chi^2$ | Df | *p* |
|---|---|---|---|---|---|---|
| Overall Model | | | | 8.58 | 3 | .04 |
| Intercept | -0.61 (1.04) | -0.59 | .56 | | | |
| DTS Total Score | -0.14 (0.30) | -0.46 | .65 | | | |
| Alcohol DSM | -0.63 (0.35) | -1.81 | .07 | | | |
| DTS x Alcohol DSM | 0.21 (0.10) | 2.02 | .04 | | | |

Note: The parameter estimates above reflect the log-odds change in AUC. Changes in AUC on the original scale (0-1) can be obtained with the following formula: Exp(β)/[1+Exp(β)].

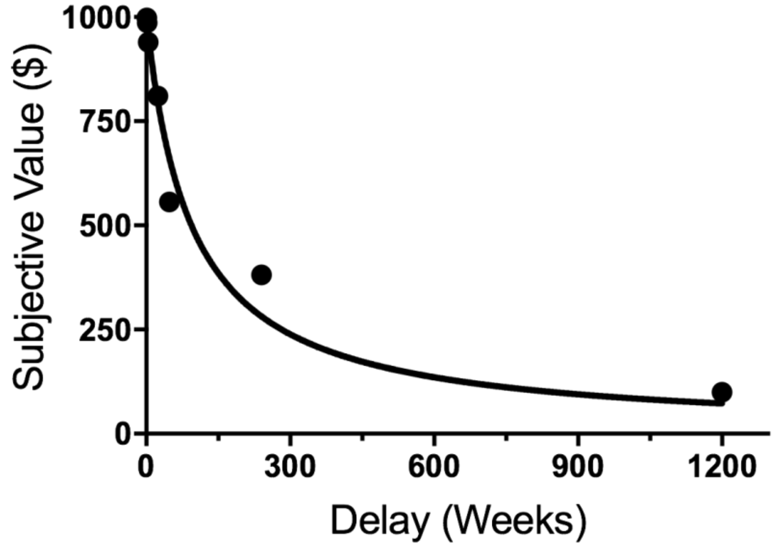


*Figure 1*. Median indifference points in the DD-ST (*n* = 59). The fitted line is the hyperbolic discounting function (Mazur, 1987), from which the best-fitting value of *k* was 0.01.

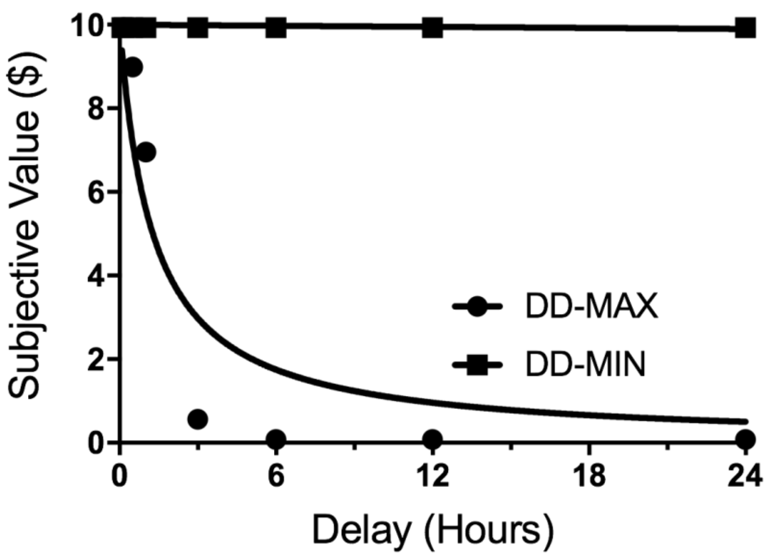


*Figure 2*. Median indifference points from DD-MIN (*n* = 57) and DD-MAX (*n* = 69). The fitted lines are the hyperbolic discounting function (Mazur, 1987), from which the best-fitting values of *k* were 0.0004 and 0.79 for DD-MIN and DD-MAX, respectively.

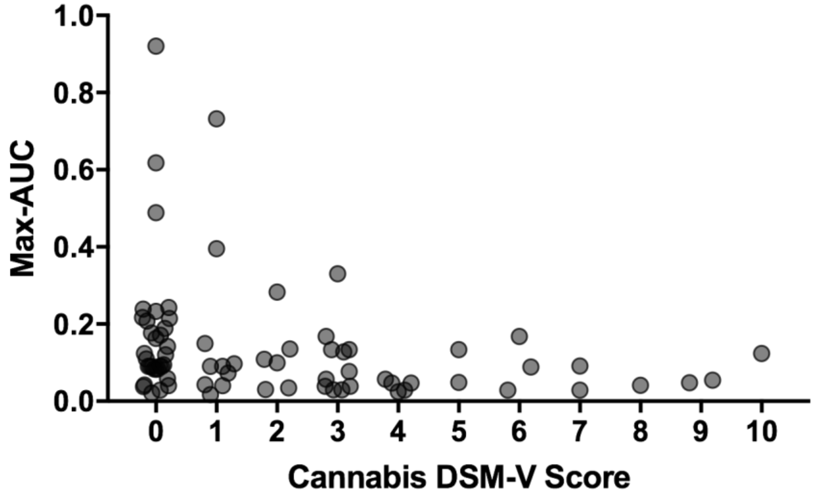


*Figure 3*. Scatterplot showing the relation between steepness of discounting in the DD-MAX as a function of DSM-5 scores for cannabis. A score of zero represents no past-year use. Data points on the x-axis are jittered for easier visualization.

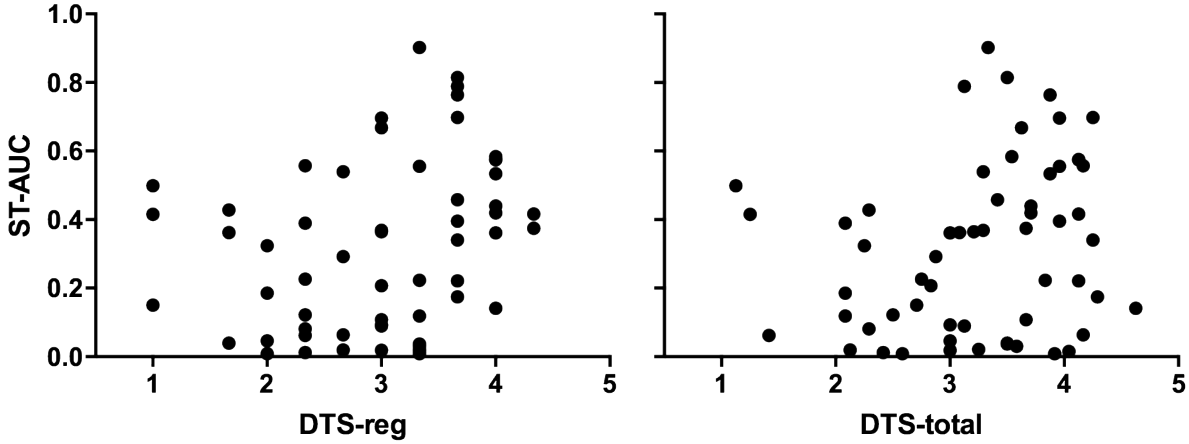


*Figure 4.* Relations between distress tolerance and steepness of delay discounting on the standard task (DD-ST). DTS-regulation subscale scores appear in the left panel and DTS-total scores in the right.

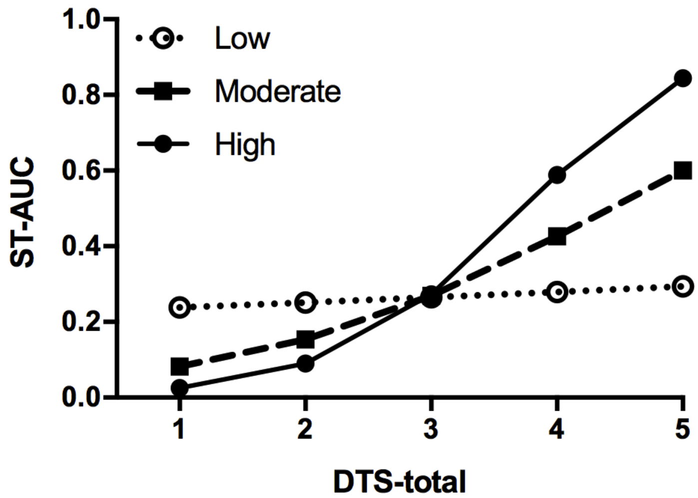


*Figure 5*. Predicted values of steepness of discounting (AUC) as a function of distress tolerance (DTS-total score), subset by level of problematic alcohol use. Low corresponds to a DSM score for alcohol of 1 (a raw value of 0, meaning no items endorsed but the participant had consumed alcohol in the past year); moderate corresponds to a value of 4 (3 items endorsed plus past-year use), and high a value of 7 (6 items endorsed plus past-year use). The predicted values are from the generalized linear model.

# Appendix A

Instructions for the Standard (DD-ST), Minimum- (DD-MIN), and Maximum Opportunity Cost (DD-MAX) Discounting Tasks

**DD-ST**

For this task, you will be asked to make choices between two money alternatives. You will not actually receive the amounts of money you choose, but we want you to respond as if you were given these options in real life. These choices will be displayed on the screen. One amount of money will always be available immediately, and the other amount will always be delayed. At times, the delay will change. If you would prefer to have the amount shown on the left, click the left option. If you would prefer to have the amount on the right, click the right option. There are no correct or incorrect choices. We are interested in which option you would prefer.

**DD-MIN**

Now you will tell us about your money preferences again. This time, I want you to imagine that if you chose the delayed money, you would be free to leave this room and go about your life as normal while waiting for the money to be automatically deposited into your bank account. If you chose the immediate money, it would be deposited in your bank account immediately after you made the choice.

Although the scenarios are pretend, we ask that you consider each scenario as if it was the only scenario you would face today.

You will now take a short quiz to confirm your understanding of these instructions. If one or more of your answers is incorrect, you will be redirected back to these instructions and have to re-take the quiz.

**DD-MAX**

Now you will tell us about your money preferences again. This time, I want you to imagine that 1) if you chose the delayed money, you would have to wait in this room for the entire time specified in the question; 2) while you waited, except for trips to the bathroom, you would have to sit in this room, alone, without using the computer; 3) you would not be allowed to sleep; and 4) you could leave for 30 minutes at mealtimes. After the waiting period is over, the money would be automatically deposited into your bank account and you would be free to go. If you chose the immediate money, it would be deposited into your bank account immediately after you made the choice.

Although the scenarios are pretend, we ask that you consider each scenario as if it was the only scenario you would face today.

You will now take a short quiz to confirm your understanding of these instructions. If one or more of your answers is incorrect, you will be redirected back to these instructions and have to re-take the quiz.

Appendix A (cont.)

DD-MAX and DD-MIN Instruction Quiz

1. If you decide to wait for the delayed money, what happens during the delay?
   - ○ I am free to leave the experiment, and can do whatever I want. *
   - ○ I must stay in this room, I have no access to any forms of entertainment, and cannot sleep while I wait. ◆

2. If you decide to wait for the delayed money, how do you collect it when the delay is over?
   - ○ It is automatically deposited into my bank account, regardless of what I am doing.*
   - ○ It is automatically deposited into my bank account, provided I have stayed in this room for the entire delay. ◆

3. If you decide to take the money now, what happens? **<u>Check all that apply</u>**.
   - ☐ The money is deposited into my bank account 1 hour after I leave.
   - ☐ The money is immediately deposited into my bank account and is immediately available to spend. *◆
   - ☐ I can leave and do whatever I want. *◆

Notes: Answers for questions 1 and 2 are mutually exclusive; only one option could be selected at a time. Multiple answers could be selected for question 3. Asterisks (*) indicate correct answers for DD-MIN, and diamonds (◆) indicate correct answers for DD-MAX.