Journal of the
Experimental Analysis of Behavior
JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2014, **9999,** 1–16 NUMBER 9999 (XXX)

CHANGE IN DELAY DISCOUNTING AND SUBSTANCE REWARD VALUE FOLLOWING A BRIEF ALCOHOL AND DRUG USE INTERVENTION

Ashley A. Dennhardt, Ali M. Yurasek, and James G. Murphy

THE UNIVERSITY OF MEMPHIS

The present study examined (1) the impact of a brief substance use intervention on delay discounting and indices of substance reward value (RV), and (2) whether baseline values and posttreatment change in these behavioral economic variables predict substance use outcomes. Participants were 97 heavy drinking college students (58.8% female, 41.2% male) who completed a brief motivational intervention (BMI) and then were randomized to one of two conditions: a supplemental behavioral economic intervention that attempted to increase engagement in substance-free activities associated with delayed rewards (SFAS) or an Education control (EDU). Demand intensity, and Omax, decreased and elasticity significantly increased after treatment, but there was no effect for condition. Both baseline values and change in RV, but not discounting, predicted substance use outcomes at 6-month follow-up. Students with high RV who used marijuana were more likely to reduce their use after the SFAS intervention. These results suggest that brief interventions may reduce substance reward value, and that changes in reward value are associated with subsequent drinking and drug use reductions. High RV marijuana users may benefit from intervention elements that enhance future time orientation and substance-free activity participation.

Key words: alcohol use, marijuana use, brief interventions, behavioral economics, delay discounting, alcohol reward value, college students

Research has shown that brief motivational interventions (BMIs) result in decreases in college student drinking and drug use (Larimer & Cronce, 2007; White, Kraus, & Swartzwelder, 2006), but effect sizes of these interventions relative to control conditions are generally small to moderate and many students who receive a BMI continue to drink heavily and experience alcohol-related problems (Carey, Scott-Sheldon, Carey, & DeMartini, 2007; Lee, Neighbors, Kilmer & Larimer, 2010; Moreira, Smith, & Foxcroft, 2009; Scott-Sheldon, Carey, Elliott, Garey, & Carey, 2014). Moreover, very few studies have examined drug use outcomes (Dennhardt & Murphy, 2013; Lee, Neighbors, Kilmer & Larimer, 2010; Lee et al 2013). There is a need for additional research that examines factors that may contribute to nonresponse and that would potentially lead to tailored interventions for individuals with specific risk profiles (Borsari, O'Leary Tevyaw, Barnett, Kahler, & Monti, 2007; Feldstein Ewing, Wray, Mead, & Adams, 2012; Murphy, Correia, Colby, & Vicinich, 2005, Murphy et al., 2012).

According to behavioral economic theory, substance use is influenced by the relative availability and price of drugs and alternative substance-free sources of reinforcement (Bickel, Johnson, Koffarnus, MacKillop & Murphy, 2014). Excessive preference for drug-related rewards may also be related to a more general tendency to devalue (discount) future outcomes or rewards, relative to immediately reinforcing stimuli such as drug use. Delay discounting and substance reward value are two behavioral economic variables that have demonstrated consistent relations with substance use in human and animal models (Cosgrove & Carroll, 2003; Higgins, Heil, & Lussier, 2004, MacKillop et al., 2011). A few preliminary studies have linked them directly with poor response to substance abuse treatment and suggest they may be viable intervention targets (Carroll, Anker, & Perry, 2009; Passetti, Clark, Mehta, Joyce, & King, 2008; Murphy et al., 2012).

Delay Discounting

Delay discounting is a behavioral measure of impulsivity that refers to the decrease in the current subjective value of a reinforcer as a function of the time until it is delivered (Ainslie, 1975). Although overall individuals prefer larger rewards to smaller rewards, if receipt of the larger reward is delayed, the individual may switch preferences and prefer the smaller reward that they could receive sooner. Alcohol and drug use provides immediate subjective reward through feelings of euphoria and stress reduction,

*Correspondence to: Ashley A. Dennhardt, Ph.D., The University of Memphis 202 Psychology Building Memphis, TN 38152 apedersn@memphis.edu
doi: 10.1002/jeab.121

whereas the potential negative consequences of the substance use are delayed. In addition, the larger rewards associated with choosing not to drink, and instead to engage in an alternative behavior, are often delayed (e.g., academic achievement, good health, vocational success). This suggests that individuals who show a strong preference for immediate rewards (and therefore devalue delayed rewards) may overvalue alcohol and drugs (Vuchinich & Simpson, 1998). However, research on discounting suggests that preferences among immediate and delayed reinforcers are not stable, and many failures of self-control may be related to the fact that the diminution in value follows a hyperbolic rather than an exponential decay function (Green & Myerson, 2004). So, the value of the delayed reward is discounted more steeply when the smaller, sooner reward is immediately available. Behavioral economic research also suggests that increasing the salience of these delayed rewards can reduce impulsive response patterns and potentially decrease substance use (Hofmeyr, Ainslie, Charlton, & Ross, 2011; Murphy et al., 2012), thus making it a potentially valuable construct to examine as an intervention target and mechanism of treatment-related change (i.e., successful treatment may work, in part, by reducing discounting).

A recent meta-analysis provides strong support for the relationship between delay discounting a variety of addictive and health-risk behavior, and particularly substance abuse (MacKillop et al., 2011). Numerous studies have demonstrated that individuals with addictive behavior patterns have higher rates of delay discounting than controls (Baker, Johnson, & Bickel, 2003; Dixon, Marley, & Jacobs, 2003; Heil, Johnson, Higgins, & Bickel, 2006; Madden, Petry, Badger, & Bickel, 1997), and a few studies suggest that elevated discounting is associated with worse response to smoking (Krishnan-Sarin et al., 2007; Yoon et al., 2007; MacKillop & Kahler, 2009), opioid (Passetti et al., 2008), and cocaine treatment (Washio et al., 2011). Given the robust link between delay discounting and substance use, discounting may be an important mechanism to target in substance abuse interventions (Bickel, Landes, Kurth-Nelson, & Redish, 2014).

Reward Value

Reward value (RV) or *reinforcing efficacy* is defined as the relative degree of preference for a reinforcer and is often measured in the laboratory by determining the amount of behavior or some other resource (e.g., time, money) that an individual will allocate towards obtaining and using a substance (Bickel et al., 2000). Measures of RV were initially developed in laboratory settings with the goal of determining the abuse liability of a drug (Hursh & Silberberg, 2008). More recently, RV has been examined as an individual difference variable in clinical samples that may predict substance use and related outcomes (MacKillop & Murphy, 2007; Murphy et al., 2005; Murphy, MacKillop, Skidmore, & Pederson, 2009; Tucker, Roth, Vignolo, & Westfall, 2009; Tucker, Vuchinich, Black, & Rippens, 2006). RV can refer to the absolute value of a substance (the amount of behavioral or resource allocation to obtain a drug in the absence of alternatives), or to the relative level of resource allocation for a drug compared to available alternatives (Epstein, Leddy, Temple, & Faith, 2007).

Demand curve indices of RV are created from hypothetical self-reported drug or alcohol purchase tasks in which the participant specifies how much of the substance he or she would purchase and use across a range of prices. A number of studies have linked demand curve indices of RV with drinking and related problems in college samples (Murphy & MacKillop, 2006; Smith et al., 2010) and there is preliminary evidence that the RV metrics generated from demand curves may be predictive of response to brief alcohol interventions among college drinkers (MacKillop & Murphy, 2007).

The *reinforcement ratio* is another behavioral economic measure of reward value that is derived from relative levels of substance-related and substance-free activity participation and enjoyment. In outpatient clinical settings where actual behavioral measurement procedures are often impractical, "reinforcement" is often operationalized as the product of recent activity participation and enjoyment, and the reinforcement ratio reflects the relative amount of recent activity participation and enjoyment that is related to substance use relative to all other activities (Correia, Carey, Simons, & Borsari, 2003). Research suggests that greater relative reinforcement from substance-related activities is related to elevated levels of substance use and problems (Correia, Carey, & Borsari, 2002; Skidmore, Murphy, & Martens, 2014). Murphy and colleagues (2005) examined the predictive utility of baseline relative reinforcement values in a sample of college students who completed a brief alcohol intervention. They found that participants who derived a greater percentage of reinforcement from substance-related activities were less likely to reduce their drinking. Additionally, participants who reduced their drinking postintervention reported increased proportional reinforcement from substance-free activities at follow-up. Taken together, these findings suggest that RV maybe a useful construct in predicting substance use severity, a potential mechanism of behavior change, and that traditional brief interventions may not be sufficient for those with high RV from substances.

In addition to being independent risk factors for substance use, delay discounting and reward value may interact to increase risk even further. For example, impulsivity (high discounting) may be a more relevant risk factor for individuals with high substance RV than for those with low substance RV. Although several studies have documented a link between high discounting and demand (MacKillop et al., 2010; Koffarnus & Woods, 2013), others have failed to do so (Diergaarde et al., 2012; Field, Christianson, Cole & Goudie, 2007; Mackillop & Tidey, 2011). Further, we are unaware of any studies that have directly examined the interaction of these two constructs as a predictor of treatment outcomes.

Taken together, these findings suggest that delay discounting and substance RV are variables that may predict substance use treatment outcomes, and may also be viable intervention targets. Murphy and colleagues (2012) developed a supplemental session, the *Substance Free Activity Session* (SFAS) that attempts to facilitate drinking reductions by targeting these mechanisms. The results of an initial pilot trial indicated that a brief motivational intervention (BMI) plus SFAS was especially helpful for students with lower substance-free activity participation and enjoyment at baseline (Murphy et al., 2012). The goal of the current study is to examine the impact of this novel intervention approach (BMI + SFAS) on delay discounting and substance reward value as well as the role these variables may play in predicting and moderating treatment response. Specifically, we will test the hypotheses that a) higher levels of delay discounting and RV will predict poor response to intervention; b) discounting and substance RV will be reduced posttreatment, and significantly more for the novel SFAS intervention; c) greater reductions in discounting and reward value at postintervention will predict greater reductions in substance use at 6-month follow-up; and d) levels of discounting and alcohol demand will interact such that those who have high levels of both will be the least likely to change after an intervention, but will experience better outcomes in the BMI + SFAS condition.

Method

Participants

Participants were 97 undergraduates (58.8% women; 41.2% men) from a large public university in the southern United States. Approximately 1,500 undergraduate students were screened for eligibility, 461were eligible, and 97 enrolled in the study. Students who enrolled were representative of the larger eligible sample on all demographic variables, but were more likely to use only alcohol (but not drugs). All enrolled participants reported heavy drinking (4/5 or more drinks for a woman/man), and 63% reported using drugs in the past month. Sixty-two percent of students reported using marijuana, 19% reported non-medical use of prescription drugs, 8% used cocaine, 6% used designer drugs and 1% reported heroin use. The sample was ethnically diverse; 59.8% identified as European American, 30.9% as African American, 5.2% as Mixed Race, 2.1% as Hispanic/Latino, 1% as Asian, and 1% as Hawaiian/Pacific Islander which overall is representative of the university demographics.

Procedure

Recruitment. All procedures were approved by the university's institutional review board. Undergraduate students were screened and recruited from the university's psychology subject pool, other undergraduate courses, and on-campus organizations and were not treatment-seeking. Students were eligible to participate in the intervention study if they were between 18–30 years old and reported one or more heavy drinking episodes (defined as five or more drinks in a sitting for a man, and 4 or more drinks for a woman) in the past month. After providing informed consent, participants completed a series of baseline questionnaires and subsequently a 30-min alcohol and drug-focused BMI. Participants were then randomized to a 30-min alcohol/drug education control session or the SFAS intervention (described below). Counselor delivered education (ED) was chosen as an active control for contact time and therapist attention. The same clinician delivered both interventions for each participant and the same group of clinicians conducted both BMI + ED and BMI + SFAS interventions. Participants completed follow-up measures at 1 and 6 months postintervention.

Interventions.

Brief motivational intervention to decrease substance use (BMI). The 25–30 min BMI included information intended to encourage students to reduce their use of alcohol and other drugs and was explicitly developed for college students with mild to moderate levels of alcohol and or drug use problems. Other research studies have used this intervention program and shown it to be efficacious (Murphy et al., 2001[C7]; Murphy, Dennhardt, Skidmore, Martens, & McDevitt-Murphy, 2010). The session began by encouraging the student to talk about his or her use of alcohol and drugs (e.g., what they like and dislike about alcohol, how their pattern of use has changed over time). They then received personalized feedback on how their drinking and drug use compares to that of other students, along with information on tolerance, and engaging in risky alcohol and drug use. The clinician discussed the feedback with the students and assisted with goal-setting and provided advice on reducing or eliminating alcohol and drug use if the student indicated he or she was interested.

Substance-free activity session (SFAS). This 25–30 min session targeted behavioral economic factors with the goal of enhancing the efficacy of the alcohol and drug BMI. Students were asked to discuss college and career goals as well as the impact of drinking/drug use on goal progress. Information on the requirements for the student's stated career goal(s) was presented as well as potential activities in which the student could participate related to these goals (e.g., organizations, internships related to their major/career goals). Students also received general information regarding financial advantages and other future benefits of graduating college and earning good grades. The session continued with feedback on how the participant currently spent their time, and the difference between time spent using substances and time spent in other activities was highlighted and discussed in relation to their goals/values. Students were also presented with information on coping skills to manage negative affect which could interfere with goal pursuit. Finally, if the student was interested, goal-setting was conducted regarding time management, grades, and valued activities. Students were asked if they would like to reconsider their substance use goals in light of the information presented. These components aimed to enhance the valuing of delayed rewards, and to increase engagement in constructive patterns of substance-free activities leading to those rewards. This was expected to reduce the relative value of substance use.

Education session. The control condition was a 25–30 min education-based control that followed the BMI. Students were given additional information about alcohol and its effects and/or drugs and related effects. The clinician talked to the student about how these substances impact the brain and nervous system, memory, sexual performance, and other areas of the body using material obtained from the National Institutes of Health NIDA website. Information about marijuana and three types of nonmedical use of prescription drugs (opioids, depressants, and stimulants) was highlighted due to the high prevalence rates of use of these drugs (SAMHSA, 2010). Students were invited to ask questions, but the session was primarily didactic.

Follow-up assessments. Students who completed the intervention were invited to complete follow-up questionnaires in the lab at 1 and 6 months after the intervention date. If they were unable to come to the lab, they were emailed a link to complete the questionnaires remotely using the secure site www.qualtrics.com. Follow-up rates did not differ by condition and there were no demographic or baseline drinking differences between completers and noncompleters.

Measures

Alcohol and marijuana use. Number of drinks per week was assessed using the Daily Drinking Questionnaire (DDQ; Collins, Parks,

& Marlatt, 1985). On the DDQ, respondents estimate the total number of standard drinks they consumed on each day during a typical week in the past month. The DDQ has been used frequently with college students and is a reliable measure that is highly correlated with self-monitored drinking reports (Kivlahan, Marlatt, Fromme, Coppel, & Williams, 1990). Participants were also asked the number of times in the past month that they engaged in a binge episode (4/5 drinks in an occasion for a man/woman) and the number of times they used marijuana (Hien & First, 1991).

Young Adult Alcohol Consequences Questionnaire (YAACQ). Alcohol-related problems were assessed using the Young Adult Alcohol Consequences Questionnaire (YAACQ; Read, Merrill, Kahler, & Strong, 2007). Participants are given a list of 49 potential problems (e.g., "I have become very rude, obnoxious, or insulting after drinking"; "I have driven a car when I knew I had too much to drink to drive safely"; "I've not been able to remember large stretches of time while drinking heavily") related to their alcohol use and asked to indicate whether or not they have experienced that problem in the past 6 months. The YAACQ has demonstrated strong psychometric properties including internal consistency and predictive validity (Read et al., 2007). Internal consistency for the YAACQ in this study was .90.

Marijuana Problems Scale (MPS). The Marijuana Problems Scale (MPS; Stephens, Roffman, & Curtin, 2000[C8]) evaluated negative social, occupational, physical, and personal consequences associated with any drug use in the past 30 days. Participants were asked to indicate whether or not their drug use caused 19 potential problems and to specify the drug they view most responsible for these problems. Marijuana was specified by 91% of participants. The MPS demonstrated good internal consistency (.86) in this sample.

Delay Discounting Task (DDT). Delayed reward discounting was also assessed using a modified version of a multi-item delay discounting task (DDT) (Amlung & MacKillop, 2011). Amlung & MacKillop used a computer program to present each option and we modified this task to create a questionnaire. In this task, participants were presented with 60 items in which they were asked to choose between two hypothetical amounts of money. For each of the 60 choices one of the amounts was a smaller, immediate reward, while the other option was a larger, delayed reward (e.g., Would you prefer $20 today, or $100 in 6 months?). The items featured varying amounts and delays; with each choice contributing to the estimate of the participant's overall discounting rate parameter (k), which was computed using a Prism graphpad macro that fitted the participant choices to a hyperbolic equation. Higher k values reflect a greater proportion of choices for the smaller immediate monetary amounts (i.e., a higher level of impulsivity). Hypothetical money choices provide a reliable and valid estimate of discounting rates, which are highly correlated with discounting estimates generated from tasks that use real monetary choices (Madden, Begotka, Raiff, & Kastern, 2003).

Measures of substance reward value.

Adolescent Reinforcement Survey Schedule-Substance Use Version (ARSS-SUV). The ARSS-SUV (Murphy et al., 2005) is a measure of past-month reinforcement from substance-related and substance-free activities. This measure was derived from Herrnstein's (1970) matching law in that it assumes reward value is best reflected in the relative degree of preference for one reinforcer relative to alternatives. Past-month activity frequency and enjoyment ratings are made with 5-point Likert scales (0–4). Frequency ratings range from 0 (zero times per week) to 4 (more than once per day), and enjoyment ratings range from 0 (unpleasant or neutral) to 4 (extremely pleasant). The frequency and enjoyment ratings are multiplied to obtain a cross-product score that reflects reinforcement derived from the activity (Correia et al., 2003). The reinforcement ratio (R-ratio), the relative reinforcing value of substance use, was then computed [(substance-related total / (substance-free total + substance-related total)].

Alcohol Purchase Task (APT). The APT is a simulation measure that assesses self-reported alcohol consumption and financial expenditure across a range of drink prices. Participants report the number of standard drinks (domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor) they would purchase and consume during a specified time frame (5 hr) at 19 price increments ranging zero (free) to $20 per drink. Demand curves are estimated by fitting each participant's reported consumption across the range of prices to Hursh and Silberberg's (2008) demand curve equation: $\log Q = \log Q0 + k\,(e^{-\alpha P} - 1)$, where Q represents the quantity consumed, $Q0$ represents consumption at price = 0, k specifies the range of the dependent variable (alcohol consumption) in logarithmic units, P specifies price, and α specifies the rate of change in consumption with changes in price (elasticity). Several RV measures are generated from the demand curve, but because we were interested in examining changes in demand resulting from treatment, we focused on the two demand indices that have demonstrated the highest test–retest reliability (*r*s = 89 - .90 over 2- week interval, Murphy et al., 2009), intensity (maximum consumption when drinks are free) and O_{max} (maximum expenditure value), as well as elasticity of demand (sensitivity of alcohol consumption to increases in cost) given its theoretical importance in behavioral economics (Hursh & Silberburg, 2008). Intensity and O_{max} are observed metrics that are computed by manually entering a) the number of drinks consumed when free and b) the largest expenditure value determined by multiplying consumption by price at every price level. Previous research indicates that these RV indices are reliable (Murphy et al., 2009), highly correlated with actual lab-based alcohol consumption (Amlung, Acker, Stojek, Murphy, & MacKillop, 2012), and associated with naturalistic levels of substance use and problems (Murphy et al., 2009).

Data Analytic Plan

Outliers were corrected using the method described by Tabachnick and Fidell (2012) in which values that are greater than or equal to 3.29 standard deviations above the mean were changed to be one unit greater than the greatest non-outlier value. Variables that were skewed or kurtotic were transformed using logarithm and square root transformations depending on which provided a better correction. Binge episodes, alcohol-related problems, marijuana use days, marijuana problems, discounting and all RV variables were log transformed. Number of drinks per week were square-root transformed. All transformations used in final analyses resulted in normal distributions except for marijuana use days and problems and delay discounting which was significantly skewed and kurtotic.

The primary outcomes from the parent trial had been submitted for publication at the time of this submission (Yurasek, Dennhardt, & Murphy, 2014). There was a reduction in drinking across both groups and a significant advantage for MI + SFAS for marijuana use days at the 6-month follow-up. The goal of the current paper is to examine the role of delay discounting and RV (intensity, $O_{max,}$ elasticity, reinforcement ratio) as predictors and outcomes of the interventions. First, in order to assess changes in discounting and RV across time and by intervention condition we conducted repeated measures ANOVAs that compared baseline to 1-month follow-up values while controlling for gender. Second, to determine whether baseline discounting, substance reinforcing value, and change in these variables predicted change in substance use and problems, we conducted a series of hierarchical regression analyses that controlled for gender, and the baseline value of the substance use variable. The change score was used in a model that also included the baseline value of the metric in order to determine the effect of change on substance use regardless of absolute baseline and 1-month levels. This study did not include a measure of marijuana reward value but the reinforcement ratio combines activities that took place while using "alcohol or drugs," and although intensity, O_{max}, and elasticity measure alcohol RV, some research suggests that greater substance use (other than alcohol) is associated with elevated alcohol demand, perhaps indicating some shared risk (Yurasek, Murphy, Clawson, Dennhardt, & MacKillop, 2013). We also conducted a series of regressions to examine if individuals with high levels of discounting and RV were more likely to have reduced levels of these constructs after a treatment (i.e., rate dependence). Ordinary least squares (OLS) multiple regression was used to examine the predictive ability of discounting and RV on alcohol use variable and negative binomial regressions were used for the marijuana use variables due to the non-normal distributions. Rate-dependent effects may obscure the effect that changes in these constructs may have on drinking or drug use reductions (see Bickel, Landes et al., 2014). Finally, a series of ANCOVAs examined the potential interaction between high and low levels of delay discounting and RV and change in substance use by condition (i.e., were those high in both more likely to change than those high in only discounting or reinforcing value).

Results

Baseline Characteristics and Adequacy of Demand and Discounting Model Fit

Overall, participants reported consuming an average of 13.49 (SD = 9.60) drinks in a typical week and a total of 11.32 (SD = 8.23) alcohol-related problems over the past month. Participants who reported using drugs in the past month (*n* = 67, 69.1% of the sample) used drugs an average of 14.22 (SD = 13.60) days in the past month and reported 4.75 (SD = 4.40) problems related to drug use in the past month. Because marijuana was the most commonly used drug (61.9% of all participants reported past month use) we examined marijuana use days as our drug use outcome. There was a significant difference in typical weekly drinking, with those assigned to BMI + SFAS drinking significantly more, but no other differences in baseline levels of outcome variables. Differences in baseline delay discounting across intervention conditions approached significance ($p = .053$) with those in the SFAS condition demonstrating higher rates of discounting. Follow-up completion rates were 88% (*N* = 85) and 67% (*N* = 65) for 1- and 6-months respectively (See Table 1 for baseline demographic statistics).

The Hursh and Silberberg (2008) exponential demand equation provided an excellent fit ($R^2 = .99$) for the aggregated data (i.e., sample mean consumption values) and a good fit for individual participant data (mean $R^2 = .85$). The discounting equation provided a good fit ($R^2 = .87$) for the aggregated data and the participant data (mean $R^2 = .86$). The authors used a similar criterion as Reynolds and Schiffbauer (2004) and included values for analyses only when the equation accounted for at least 30% of the variance (one participant was excluded from the elasticity analyses and zero from discounting for this reason).

Correlations between baseline alcohol and marijuana use variables and behavioral economic variables are shown in Table 2. There were moderate to strong positive associations between the reinforcement ratio and typical weekly drinking, binge drinking, marijuana use days, alcohol problems, and marijuana problems. Intensity, O_{max}, and elasticity were correlated with drinks per week and binge drinking. Intensity was also significantly correlated with alcohol and marijuana problems.

Table 1

Baseline demographic and substance use characteristics

	Total Sample	SFAS	Education
N	97	50	47
Age—*M* (SD)	20.10 (2.23)	20.14 (2.32)	20.06 (2.16)
Gender—(%)			
Male	40 (41.2)	21 (42.0)	19 (40.4)
Female	57 (58.8)	29 (58.0)	28 (59.6)
Race/Ethnicity—(%)			
White or Caucasian	58 (59.8)	30 (60.0)	28 (59.6)
Black or African-American	30 (30.9)	15 (30.0)	15 (31.9)
Other	2 (9.3)	5 (10.0)	4 (8.5)
Class—(%)			
Freshman	52 (54.2)	28 (57.1)	24 (51.1)
Sophomore	16 (16.7)	6 (12.2)	10 (21.3)
Junior	14 (14.6)	5 (10.2)	9 (19.1)
Senior	12 (12.5)	8 (16.3)	4 (8.5)
Other[1]	2 (2.1)	2 (4.1)	0 (0)
Drinks Per Week	13.49 (9.60)	15.34 (9.90)	11.53 (8.97)
Past Month Binge Episodes	4.01 (3.84)	4.74 (4.17	3.23 (3.32)
Alcohol Related Problems (0–49)	11.32 (8.23)	11.72 (8.60)	10.89 (7.89)
Past Month Marijuana Use Days	12.22 (10.67)	12.45 (10.74)	11.97 (10.77)
Past Month Drug Problems (0–19)	3.01 (4.26)	3.20 (4.11)	2.80 (4.25)

Note. [1]Participants categorized as "other" were students who were either in between years (i.e., third semester junior) or those who declined to answer.

Table 2

Correlations between substances use and behavioral economic variables

	1	2	3	4	5	6	7	8	9	10
1. Drinks Per Week	–	.590**	.480**	.330**	.205*	.390*	.289*	–.265*	.437**	–.029
2. Binge Episodes	–	–	.350**	.219*	.145	.267*	.227*	–.217*	.382*	–.063
3. Alcohol Problems	–	–	–	.121	.394**	.391**	.189	–.050	.352**	.020
4. Marijuana Days	–	–	–	–	.712**	.072	–.070	–.027	.482**	.074
5. Drug Use Problems	–	–	–	–	–	.188	–.055	.040	.467**	.032
6. Intensity	–	–	–	–	–	–	.493**	–.385**	.209	.071
7. O_{max}	–	–	–	–	–	–	–	–.835**	.131	.036
8. Elasticity	–	–	–	–	–	–	–	–	–.169	–.017
9. Reinforcement Ratio	–	–	–	–	–	–	–	–	–	–.142
10. Delay Discounting	–	–	–	–	–	–	–	–	–	–

*$p \leq .05$.
**$p \leq .01$.

Delay discounting was not significantly correlated with any substance use variables.

Change in Delay Discounting and RV by Condition

A series of time by group (2 × 2) repeated-measures ANOVAs were used to examine change in RV and discounting variables at 1-month postintervention. Means, standard deviations, and within-subjects effect sizes for discounting and RV variables are presented in Table 3. There were significant reductions in intensity ($F(1, 74) = 22.81$, $p < .001$, $\eta p^2 = .24$) and O_{max} values ($F\ (1,\ 77) = 15.91$, $p < .001$, $\eta p^2 = .17$) and an increase in elasticity values (greater elasticity = more price sensitivity) ($F\ (1,\ 66) = 18.97$, $p < .001$, $\eta p^2 = .22$) across conditions. There were no significant condition effects and there were no significant changes in discounting or the reinforcement ratio from baseline to 1 month.

Predictive Utility of Discounting and Substance RV

Drinks per week, binge drinking, alcohol problems, marijuana use days, and marijuana-related problems at 6 months were regressed on discounting and reward value variables

Table 3

Baseline and one-month follow-up means (sd) and effect sizes for behavioral economic variables by treatment condition.

	Baseline		1 month follow-up		Baseline to 1 month
Variable	Mean	SD	Mean	SD	d
Intensity					
MI + SFAS ($n = 44$)	9.60	5.14	6.31	3.39	.76
MI +EDU ($n = 33$)	8.79	5.17	6.39	4.02	.52
O_{max}					
MI + SFAS ($n = 44$)	17.47	9.98	15.55	11.18	.19
MI +EDU ($n = 36$)	18.83	11.05	12.79	9.64	.55
Elasticity					
MI + SFAS ($n = 39$)	.0057	.0027	.0067	.0042	.29
MI +EDU ($n = 30$)	.0065	.0050	.0083	.0062	.37
R-ratio					
MI + SFAS ($n = 38$)	.3076	.1620	.2636	.2029	.24
MI +EDU ($n = 31$)	.2968	.1800	.2308	.1959	.35
Delay Discounting					
MI + SFAS ($n = 44$)	.0713	.0350	.0726	.1410	–.01
MI +EDU ($n = 38$)	.0264	.0293	.0527	.1228	–.36

Note. MI = Motivational Intervention, SFAS = Substance Free Activity Session, EDU = Education control, ns differed slightly, means reported are for sample size used for baseline to one month comparisons. Positive effect sizes reflect an improvement in the variable. There were no significant differences between conditions.

separately (See Tables 4 & 5). Baseline values of discounting and reward value variables were entered in the first block of the regression equation along with the baseline value of each DV (e.g., drinks per week) and gender as covariates. The change from baseline to 1 month was entered in the next block.

Baseline discounting and RV values. Baseline intensity was significantly associated with binge drinking, alcohol-related problems, and

Table 4

Regression results for post-treatment changes in behavioral economic variables predicting alcohol use variables at six-month follow-up

	B	SEB	β	*t*	p-value	ΔR^2
Change in intensity predicting substance use						
Typical drinking						
Baseline Intensity	4.24	2.63	.299	1.61	.113	.000
Δ Intensity	−.755	.413	−.314	−1.83	.073	.033
Binge Drinking						
Baseline Intensity	1.74	.801	.475	2.17	.035*	.007
Δ Intensity	−.260	.125	−.421	−2.08	.043*	.053
Alcohol problems						
Baseline Intensity	2.22	.819	.494	2.71	.009*	.001
Δ Intensity	−.471	.128	−.619	−3.68	.001*	.147
Change in O_{max} predicting substance use						
Typical drinking						
Baseline O_{max}	3.33	1.19	.322	2.80	.007*	.032
Δ O_{max}	−.398	.166	−.277	−2.40	.020*	.052
Binge Drinking						
Baseline O_{max}	.795	.349	.292	2.28	.027*	.032
Δ O_{max}	−.084	.047	−.227	−1.79	.079	.038
Alcohol Problems						
Baseline O_{max}	.340	.383	.103	.887	.379	.002
Δ O_{max}	−.182	.052	−.398	−3.46	.001*	.133
Change in elasticity predicting substance use						
Typical drinking						
Baseline elasticity	−249.19	113.74	−.247	−2.191	.033*	.029
Δ elasticity	−102.47	50.525	−.243	−2.028	.048*	.043
Binge Drinking						
Baseline elasticity	−69.38	32.22	−.257	−2.15	.036*	.039
Δ elasticity	−25.973	14.18	−.229	−1.83	.073	.041
Alcohol problems						
Baseline elasticity	−35.19	38.84	−.109	−.906	.369	.004
Δ elasticity	−29.50	17.66	−.220	−1.67	.101	.038
Change in R-ratio predicting substance use						
Typical drinking						
Baseline R-ratio	−5.005	3.306	−.184	−1.51	.137	.026
Δ R-ratio	−1.713	3.761	−.049	−.456	.651	.002
Binge drinking						
Baseline R-ratio	−1.026	1.025	−.143	−1.00	.322	.015
Δ R-ratio	−1.702	1.116	−.186	−1.53	.134	.032
Alcohol problems						
Baseline R-ratio	.311	1.110	.036	.280	.780	.001
Δ R-ratio	−3.28	1.324	−.296	−2.48	.017*	.078
Change in discounting predicting substance use						
Typical drinking						
Baseline Discounting	−1.727	4.391	−.042	−.393	.696	.010
Δ Discounting	−8.42	4.76	−.193	−1.78	.082	.030
Binge drinking						
Baseline Discounting	−1.78	1.24	−.166	−1.44	.157	.036
Δ Discounting	−.932	1.34	−.083	−.697	.489	.006
Alcohol problems						
Baseline Discounting	−1.62	1.51	−.122	−1.08	.287	.021
Δ Discounting	−1.178	1.60	−.084	−.737	.464	.006

Table 5

Negative binomial regression results for post-treatment changes in behavioral economic variables predicting marijuana variables at six-month follow-up

Variable	b	SE b	Wald χ2	p-value
Change in intensity predicting substance use				
Marijuana Use				
Baseline Intensity	.033	.055	.360	.548
Δ Intensity	−.304	.075	16.30	.000*
Marijuana Problems				
Baseline Intensity	.134	.0723	3.46	.063
Δ Intensity	−2.85	.090	9.94	.002*
Change in O_{max} predicting substance use				
Marijuana Use				
Baseline O_{max}	−.051	.019	6.78	.009*
Δ O_{max}	−.027	.021	1.78	.182
Marijuana Problems				
Baseline O_{max}	−.035	.027	1.70	.192
Δ O_{max}	−.050	.30	2.79	.095
Change in elasticity predicting substance use				
Marijuana Use				
Baseline elasticity	1.25	57.10	.000	.983
Δ elasticity	36.75	36.96	.989	.320
Marijuana Problems				
Baseline elasticity	28.05	56.58	.246	.620
Δ elasticity	−69.52	63.81	1.19	.276
Change in R-ratio predicting substance use				
Marijuana Use				
Baseline R-ratio	4.98	1.01	24.24	.000*
Δ R-ratio	−8.06	1.57	26.45	.000*
Marijuana Problems				
Baseline R-ratio	3.70	1.51	6.01	.014*
Δ R-ratio	1.54	1.91	.651	.420

Note: Analyses examining delay discounting are not shown due to the omnibus model not reaching significance.

days of marijuana use at 6-month follow-up (see Tables 4 & 5 for regression results). Higher baseline O_{max} was associated with more drinks per week, binge episodes, and marijuana use days at 6-month follow-up. Lower baseline levels of elasticity were associated with more drinks per week and binge episodes at 6-month follow-up. Higher levels of the baseline reinforcement ratio predicted more marijuana use days and problems at 6-month follow-up. Baseline delay discounting values did not predict any substance use variables at 6 months.

Change in discounting and RV from baseline to 1-month. Greater decreases in intensity were related to significantly lower binge drinking, and trend-level reductions in weekly drinking at 6-month follow-up. Greater deceases in O_{max} predicted significantly fewer drinks per week and alcohol-related problems, and trend level reductions in binge drinking, at the 6-month follow-up. Increases in elasticity were associated with significantly fewer drinks per week and trend-level reductions in binge episodes. Decreases in reinforcement ratio predicted fewer alcohol-related problems at 6-month follow-up. Decreases in discounting were associated with trend-level reductions in drinks per week.

Decreases in intensity were significantly associated with fewer marijuana use days and marijuana-related problems at 6-month follow-up. Decreases in R-ratio were associated with fewer marijuana days at 6-month follow-up. Changes in O_{max}, elasticity and discounting did not predict 6-month marijuana use.[1]

Supplemental analyses (available from the authors upon request) examined rate dependence using the method outlined by Bickel, Landes et al. (2014). For discounting and each

[1] Additional analyses were conducted to examine change in intensity, O_{max} and elasticity as mediators of the effect of treatment condition on marijuana use days. Preacher & Hayes' (2008) bootstrapping methodology for indirect effects based on 5000 bootstrap resamples to describe the confidence intervals of indirect effects revealed no significant mediation effects.

RV variable, change was regressed on baseline level of that variable centered about its mean. CIs for the intercept from these regressions provide a goodness-of-fit test for regression to the mean; CIs containing 0 imply that regression to the mean is a plausible explanation of any rate-dependent effect. A bootstrap method was also used (using 1,000 bootstrapped samples per study group) to obtain a nonparametric verification of regression to the mean's goodness of fit. Intensity, $O_{max,}$ and discounting had improved postintervention rates relative to pretreatment levels, and individuals with higher intensity, $O_{max,}$ R-ratio and discounting at baseline tended to improve their rates of these variables more; however, the change in discounting was likely due to regression to the mean. Thus only intensity and O_{max}, showed evidence of rate dependence suggesting that those who were higher on intensity and O_{max} were more likely to improve on these indices and that this was not likely explained by regression to the mean. Although there was evidence of rate dependence on reinforcement ratio, the confidence interval of the intercept included 0 and therefore indicated that regression to the mean likely explains this finding. There was no evidence of rate dependence for elasticity.

Discounting and reinforcing value matrix. A series of ANCOVAs were used to examine the potential interaction between levels of delay discounting and RV, and change in substance use variables (typical drinking, binge drinking, alcohol problems, marijuana days, and marijuana use problems) by condition. A composite variable for RV was created by taking the average of the *z* scores for O_{max} and elasticity. O_{max} and elasticity were selected because they were related to 6-month substance use outcomes and previous research indicates that they form a coherent factor that reflects price sensitivity (MacKillop et al., 2009). Median splits were used to categorize individuals as high or low on this composite of RV and on delay discounting, and individuals were then categorized as being high in both (RV and discounting), low in both, high in RV only, or high in discounting only. There was a main effect for the RV-discounting matrix variable on 6-month binge drinking after controlling for condition and baseline drinking level (F (3,50) = 3.68; p=.018. Follow-up contrasts indicated that those who had high RV only (low discounting) had higher levels of postintervention drinking than those who had high discounting only (low demand) (p=.009) or those who were low in both discounting and RV (p=.003). There was no condition by matrix interaction. There was a significant matrix by condition interaction (F (3,52) = 3.98; p=.013) on marijuana use days at 6-month follow-up. Participants who were high in RV and in the SFAS condition reduced their marijuana use days at 6 months whereas those with high RV in the education condition and those with low RV in either condition did not. (See Fig. 1).

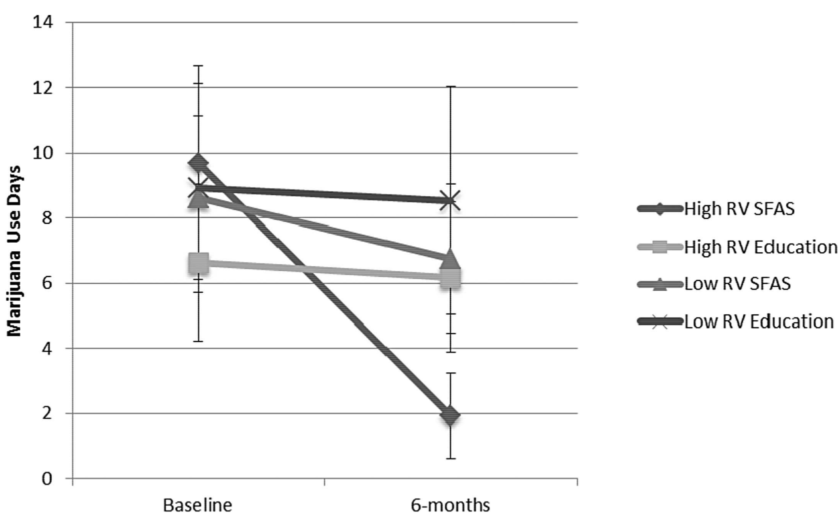

Fig. 1. Change in marijuana use days by reinforcing value (rv) status and condition.

Discussion

The goal of this study was to examine delay discounting and RV as predictors of outcomes following a brief substance use intervention (BMI + SFAS) that directly targeted these mechanisms. The effect of baseline levels of and the change in the RV and discounting variables on response to intervention was examined, as was the direct effect of the interventions on these variables. Overall, RV (specifically alcohol demand) was significantly reduced after a BMI, but there was no additional advantage for a supplemental behavioral economic session. Several measures of RV (Intensity, $O_{max,}$ and elasticity) were predictive of greater drinking at 6-month follow-up, suggesting that those with higher demand for alcohol may have a more difficult time moderating their drinking after a brief intervention than those with lower demand. This is consistent with a previous study that indicated that elevated alcohol demand predicted poor treatment response (MacKillop & Murphy, 2007). Changes (improvements) in these RV metrics were even more robust predictors of substance use outcomes at 6-month follow-up. Change in RV was most predictive of change in marijuana and alcohol problems, with changes in intensity showing the largest effect sizes (accounting for 11–15% of the variance in follow-up marijuana and alcohol problems, respectively). Change in O_{max} accounted for 13% of the variance in follow-up drinking.

There were significant changes (improvements) in intensity, $O_{max,}$ and elasticity after the brief intervention and, as noted above, change in these variables predicted less follow-up drinking and/or problems. Although there was not a significant group-level change in reinforcement ratio, posttreatment decreases in this variable predicted lower levels of alcohol problems and marijuana use at the 6-month follow-up. Although one previous study demonstrated that individuals who derive a large proportion of their total reinforcement from substance-related activities report more drinking after an intervention (Murphy et al., 2005), this is the first study to show this relationship with marijuana use. It is of note that rate-dependence analyses of this variable suggest regression to the mean cannot be ruled out as an explanation for this finding and thus attempts at replication should be made. Overall, consistent with behavioral economic theory, individuals for whom substances provide the most reliable source of reinforcement may be less able to reduce marijuana use or to modify their drinking in order to avoid alcohol problems Bickel, Landes et al. 2014). It is interesting that change in intensity, a measure of alcohol demand, was associated with fewer marijuana-related problems postintervention, and that participants with higher levels of alcohol demand reduced the number of days they used marijuana after a BMI + supplemental intervention that aimed to increase involvement in substance-free activities (SFAS) compared to those in a BMI plus education control condition. These results suggest that high alcohol demand may also be a risk factor for marijuana use (Yurasek et al., 2013) and that reducing alcohol demand may lead to reductions in marijuana use. Thus, it is possible that a behavioral economic intervention may help those with high RV to reduce their marijuana use, perhaps by increasing the valuation of alternative reinforcers.

Surprisingly, discounting was not predictive of response to intervention nor did it change following a brief substance use intervention that attempted to increase future orientation. Further, higher level of discounting did not seem to interact with high RV to increase risk of nonresponse to intervention, nor was it correlated with any substance use variables at baseline. Although there was a trend-level finding that decreases in discounting were associated with drinking reductions, the general pattern of null results for discounting is inconsistent with the literature that suggests that lower levels of delay discounting are related to less drinking and fewer alcohol-related problems (MacKillop, Mattson, MacKillop, Castelda, & Donovick, 2007), and that higher discounting is related to higher levels of substance use after an intervention (Passetti et al., 2008 MacKillop & Kahler, 2009; Stanger et al., 2012; Yoon et al., 2007). However, there have also been studies that have found that discounting is not related to substance use after treatment in adult marijuana users (Peters, Petry, LaPaglia, Reyonds, & Carroll, 2013). A previous study with a similar sample of college drinkers and intervention approaches found that the BMI + SFAS intervention increased scores on a self-report index of the Consideration of Future Consequences (Murphy et al., 2012) but did not impact delay discounting (nor did discounting predict outcomes in that study). Monetary choice measures of discounting may be less useful with college students given their limited income and limited experience with savings (Dennhardt & Murphy, 2011). Interestingly, discounting has predicted outcomes with adolescent substance abusers who likely have similar income profiles, but more severe substance use patterns (Stanger et al., 2012), so it is also possible that discounting is a more relevant risk factor for more severe populations.

Implications and Future Directions

These results are consistent with behavioral economic theory and suggest that, overall, elevated RV is a risk factor for poorer response to enhanced BMI interventions, but that these interventions are associated with change in RV and that the degree of reduction in RV may be a clinically useful index of response to intervention and need for further treatment. Additionally, individuals who have high alcohol demand and use marijuana may be ideal candidates for an enhanced BMI intervention that includes behavioral economic elements. A previous study found that the behavioral economic SFAS session also resulted in greater reductions in alcohol problems, but that finding was not replicated in the current study, perhaps due to the shorter SFAS session length (30 min in the current study compared to 60 min in Murphy et al., 2012). Future research should continue efforts to develop translational research interventions that target variables that have been identified as risk factors for poor intervention response. Future research should also evaluate the utility of matching individuals to more versus less intensive interventions based on ongoing measurement or substance reinforcing value.

Limitations. A notable limitation of this study is the relatively small sample size, the small percentage of eligible participants enrolled, and moderate levels of 6-month attrition that may have limited our ability to detect predictive outcomes and prevented us from evaluating formal moderation. There were also baseline group differences in drinking and delay discounting, and although we controlled for baseline levels of these variables in our analyses, this difference may have impacted the analyses examining group effects on these constructs. Another limitation is that this study did not include a no-intervention control condition. Although we hypothesized that the SFAS, which directly targets RV and delay discounting, would have larger effects on these variables, all participants received an alcohol BMI that focused on the negative consequences of drinking and this may have impacted these variables as well. Further, this study did not include measurement of discounting or RV immediately after the intervention (first post-intervention measurement was at 1 month). It is possible that if the SFAS intervention did impact discounting it may have done so in a manner not detected by our hypothetical monetary choice measure, or that the effect may have dissipated over time. Another limitation is that this study included a single measure of discounting that assessed choices with one larger delayed reward amount. Some research suggests that using measures that assess choices over a larger range of reward magnitudes may be beneficial (Green et al., 1997; Green, Myerson, & McFadden, 1997). More frequent and precise measurement using experiential (Reynolds & Schiffbauer, 2004) or nonmonetary discounting indices, as well as paper–pencil measures of related constructs such as time orientation (Murphy et al., 2012), may have also been beneficial in detecting what may be small, potentially unstable effects. Further, although our results suggesting that alcohol demand is relevant to marijuana use outcomes is interesting, future research should include a measure of marijuana demand (Collins, Vincent, Yu, Liu, & Epstein, 2014). Finally, although research has shown that college student self-report measures of substance use are generally accurate (Hagman, Clifford, Noel, Davis, & Cramond, 2007), a biological measure of alcohol or marijuana use may have been helpful in confirming these results.

Despite these limitations, these results extend the extant literature by suggesting that the behavioral economic variable of RV is an indicator of substance use pathology and, most importantly, that change in RV is an important predictor of response to substance use interventions in college students (Bickel, Johnson et al., 2014). Future research should study the utility of RV as a mechanism of change by including more precise and frequent measures of demand and relative substance-related reinforcement. These indices may also be useful for identifying individuals who have not responded to an intervention and who may require alternate or more intensive intervention. Hypothetical money choice measures of delay discounting may be less useful predictors of intervention outcomes in nontreatment seeking college samples.

References

Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin, 82*(4), 463–496.

Amlung, M. T., Acker, J., Stojek, M. K., Murphy, J. G., & MacKillop, J. (2012). Is talk "cheap"? An initial investigation of the equivalence of alcohol purchase task performance for hypothetical and actual rewards. *Alcoholism: Clinical and Experimental Research, 36*(4), 716–724. DOI: 10.1111/j.1530–0277.2011.01656.x.

Amlung, M., & MacKillop, J. (2011). Delayed reward discounting and alcohol misuse: The roles of response consistency and reward magnitude. *Journal of Experimental Psychopathology, 2*(3), 418–431.

Baker, F., Johnson, M., & Bickel, W. (2003). Delay discounting in current and never-before cigarette smokers: Similarities and differences across commodity, sign, and magnitude. *Journal of Abnormal Psychology, 112*(3), 382–392.

Bickel, W. K., Jarmolowicz, D. P., MacKillop, J., Epstein, L. H., Carr, K., Mueller, E. T. & Waltz, T. J.. (2012). The behavioral economics of reinforcement pathologies. In H. J. Shaffer (Ed.), *Addiction syndrome handbook.* Washington, DC: American Psychological Association.

Bickel, W. K., Johnson, M. W., Koffarnus, M. N., MacKillop, J., & Murphy, J. G. (2014). The behavioral economics of Substance Use Disorders: Reinforcement pathologies and their repair. *Annual Review of Clinical Psychology, 13*, 20.1–20.37.

Bickel, W. K., Landes, R. D., Kurth-Nelson, Z., & Redish, D. (2014). A quantitative signature of self-control repair: Rate-dependent effects of successful addiction treatment. *Clinical Psychological Science*, 1–11.

Borsari, B., Tevyaw, T., Barnett, N. P., Kahler, C. W., & Monti, P. M. (2007). Stepped care for mandated college students: A pilot study. *The American Journal on Addictions, 16*(2), 131–137. DOI: 10.1080/10550490601184498.

Carey, K. B., Scott-Sheldon, L., Carey, M. P., & DeMartini, K. (2007). Individual-level interventions to reduce college student drinking: A meta-analytic review. *Addictive Behaviors, 32*, 2469–2494.

Carroll, M. E., Anker, J. J., & Perry, J. L. (2009). Modeling risk factors of nicotine and other drug abuse in the preclinical laboratory. *Drug and Alcohol Dependence, 104*, S70–S78.

Collins, R., Parks, G., & Marlatt, G. (1985). Social determinants of alcohol consumption: The effects of social interaction and model status on the self-administration of alcohol. *Journal of Consulting and Clinical Psychology, 53*(2), 189–200.

Collins, R., Vincent, P. C., Yu, J., Liu, L., & Epstein, L. H. (2014). A behavioral economic approach to assessing demand for marijuana. *Experimental and Clinical Psychopharmacology, 22*(3), 211–221. DOI: 10.1037/a0035318.

Correia, C. J., Carey, K. B., & Borsari, B. (2002). Measuring substance-free and substance-related reinforcement in the natural environment. *Psychology of Addictive Behaviors, 16*(1), 28.

Correia, C. J., Carey, K. B., Simons, J., & Borsari, B. E. (2003). Relationships between binge drinking and substance-free reinforcement in a sample of college students: A preliminary investigation. *Addictive Behaviors, 28*, 361–368.

Cosgrove, K. P., & Carroll, M. E. (2003). Effects of a non-drug reinforcer, saccharin, on oral self-administration of phencyclidine in male and female rhesus monkeys. *Psychopharmacology, 170*(1), 9–16.

Dennhardt, A. A., & Murphy, J. G. (2011). Associations between depression, distress tolerance, delay discounting, and alcohol-related problems in European American and African American college students. *Psychology of Addictive Behaviors, 25*(4), 595.

Dennhardt, A. A., & Murphy, J. G. (2013). Prevention and treatment of college student drug use: A review of the literature. *Addictive Behaviors, 38*(10), 2607–2618. DOI: 10.1016/j.addbeh.2013.06.006.

Diergaarde, L., Van Mourik, Y., Pattij, T., Schoffelmeer, A. N., & De Vries, T. J. (2012). Poor impulse control predicts inelastic demand for nicotine but not alcohol in rats. *Addiction Biology, 17*(3), 576–587.

Dixon, M., Marley, J., & Jacobs, E. (2003). Delay discounting by pathological gamblers. *Journal of Applied Behavior Analysis, 36*(4), 449–458.

Epstein, L. H., Leddy, J. J., Temple, J. L., & Faith, M. S. (2007). Food reinforcement and eating: a multilevel analysis. *Psychological Bulletin, 133*(5), 884.

Feldstein Ewing, S. W., Wray, A. M., Mead, H. K., & Adams, S. K. (2012). Two approaches to tailoring treatment for cultural minority adolescents. *Journal of Substance Abuse Treatment, 432*, 190–203. DOI: 10.1016/j.jsat.2011.12.005.

Field, M., Christiansen, P., Cole, J., & Goudie, A. (2007). Delay discounting and the alcohol Stroop in heavy drinking adolescents. *Addiction, 102*(4), 579–586.

Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin, 130*, 769–792.

Green, L., Myerson, J., & McFadden, E. (1997). Rate of temporal discounting decreases with amount of reward. *Memory and Cognition, 25*, 715–723.

Hagman, B. T., Clifford, P. R., Noel, N. E., Davis, C. M., & Cramond, A. J. (2007). The utility of collateral informants in substance use research involving college students. *Addictive Behaviors, 32*(10), 2317–2323.

Heil, S., Johnson, M., Higgins, S., & Bickel, W. (2006). Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. *Addictive Behaviors, 31*(7), 1290–1294.

Herrnstein, R. J. (1970). On the Law of Effect. *Journal of the Experimental Analysis of Behavior, 13*(2), 243–266.

Hien, D. A., & First, M. (1991). Drug Use Questionnaire. Unpublished scale, Columbia College of Physicians and Surgeons, New York State Psychiatric Institute.

Higgins, S. T., Heil, S. H., & Lussier, J. (2004). Clinical implications of reinforcement as a determinant of Substance Use Disorders. *Annual Review of Psychology, 55*, 431–461.

Hofmeyr, A., Ainslie, G., Charlton, R., & Ross, D. (2011). The relationship between addiction and reward bundling: An experiment comparing smokers and non-smokers. *Addiction, 106*(2), 402–409.

Hursh, S. R., & Silberberg, A. (2008). Economic demand and essential value. *Psychological Review, 115*, 186–198.

Kivlahan, D., Marlatt, G., Fromme, K., Coppel, D., & Williams, E. (1990). Secondary prevention with college drinkers: Evaluation of an alcohol skills training program. *Journal of Consulting and Clinical Psychology, 58*(6), 805–810.

Koffarnus, M. N., & Woods, J. H. (2013). Individual differences in discount rate are associated with demand for self-administered cocaine, but not sucrose. *Addiction Biology, 18*(1), 8–18. DOI: 10.1111/j.1369–1600.2011.00361.x.

Krishnan-Sarin, S., Reynolds, B., Duhig, A. M., Smith, A., Liss, T., McFetridge, A., & Potenza, M. N. (2007). Behavioral impulsivity predicts treatment outcome in a smoking cessation program. *Drug and Alcohol Dependence, 88*, 79–82.

Larimer, M. E., & Cronce, J. M. (2007). Identification, prevention, and treatment revisited: Individual-focused college drinking prevention strategies 1999-2006. *Addictive Behaviors, 32*, 2439–2468.

Lee, C. M., Kilmer, J. R., Neighbors, C., Atkins, D. C., Zheng, C., Walker, D. D., & Larimer, M. E. (2013). Indicated prevention for college student marijuana use: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 81*(4), 702–709.

Lee, C., Neighbors, C., Kilmer, J., & Larimer, M. (2010). A brief, web-based personalized feedback selective intervention for college student marijuana use: A randomized clinical trial. *Psychology of Addictive Behaviors, 24*(2), 265–273. DOI: 10.1037/a0018859.

MacKillop., J., Amlung, M. T., Pryor, L. R., Ray, L. A., Sweet, L. H., & Munafo, M. R. (2011). Delayed reward discounting and addictive behavior: A meta-analysis. *Psychopharmacology, 216*(3), 305–321.

MacKillop, J., & Kahler, C. W. (2009). Delayed reward discounting predicts treatment response for heavy drinkers receiving smoking cessation treatment. *Drug and Alcohol Dependence, 104*, 197–203.

MacKillop, J., Mattson, R. E., MacKillop, E., Castelda, B. A., & Donovick, P. J. (2007). Multidimensional assessment of impulsivity in undergraduate hazardous drinkers and controls. *Journal of Studies on Alcohol and Drugs, 68* (6), 785–788.

MacKillop, J., Miranda, R. R., Monti, P. M., Ray, L. A., Murphy, J. G., Rohsenow, D. J., ... Gwaltney, C. J. (2010). Alcohol demand, delayed reward discounting, and craving in relation to drinking and alcohol use disorders. *Journal of Abnormal Psychology, 119*(1), 106–114. DOI: 10.1037/a0017513.

MacKillop, J., & Murphy, J. (2007). A behavioral economic measure of demand for alcohol predicts brief intervention outcomes. *Drug and Alcohol Dependence, 89*, 227–233.

MacKillop, J., & Tidey, J. W. (2011). Cigarette demand and delayed reward discounting in nicotine-dependent individuals with schizophrenia and controls: An initial study. *Psychopharmacology, 216*(1), 91–99. DOI: 10.1007/s00213–011-2185–8.

Madden, G., Begotka, A., Raiff, B., & Kastern, L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology, 11*(2), 139–145.

Madden, G., Petry, N., Badger, G., & Bickel, W. (1997). Impulsive and self-control choices in opioid-dependent patients and non-drug-using control patients: Drug and monetary rewards. *Experimental and Clinical Psychopharmacology, 5*(3), 256–262.

Moreira, M. T., Smith, L. A., & Foxcroft, D. (2009). Social norms interventions to reduce alcohol misuse in University of College students. *Cochrane Database of Systematic Reviews, 3*, DOI: 10.1002/14651858.CD006748.pub2.

Murphy, J. G., Correia, C. J., Colby, S. M., & Vuchinich, R. E. (2005). Using behavioral theories of choice to predict drinking outcomes. *Experimental and Clinical Psychopharmacology, 13*, 93–101.

Murphy, J. G., Dennhardt, A. A., Skidmore, J. R., Borsari, B., Barnett, N. P., Colby, S. M., & Martens, M. P. (2012). A randomized controlled trial of a behavioral economic supplement to brief motivational interventions for college drinking. *Journal of Consulting and Clinical Psychology, 80*(5), 876–886. DOI: 10.1037/a0028763.

Murphy, J. G., Dennhardt, A. A., Skidmore, J. R., Martens, M. P., & McDevitt-Murphy, M. E. (2010). Computerized versus motivational interviewing alcohol interventions: Impact on discrepancy, motivation, and drinking. *Psychology of Addictive Behaviors, 24*(4), 628–639. DOI: 10.1037/a0021347.

Murphy, J. G., Duchnick, J. J., Vuchinich, R. E., Davison, J. W., Karg, R. S., Olson, A. M., ... Coffey, T. T. (2001). Relative efficacy of a brief motivational intervention for college student drinkers. *Psychology of Addictive Behaviors, 15*, 373–379.

Murphy, J. G., & MacKillop, J. (2006). Relative reinforcing efficacy of alcohol among college student drinkers. *Experimental Clinical Psychopharmacology, 14*, 219–227.

Murphy, J. G., MacKillop, J., Skidmore, J. R., & Pederson, A. A. (2009). Reliability and validity of a demand curve measure of alcohol reinforcement. *Experimental Clinical Psychopharmacology, 17*, 396–404.

Passetti, F., Clark, L., Mehta, M. A., Joyce, E., & King, M. (2008). Neuropsychological predictors of clinical outcome in opiate addiction. *Drug and Alcohol Dependence, 94*, 82–91.

Peters, E. N., Petry, N. M., LaPaglia, D. M., Reynolds, B., & Carroll, K. M. (2013). Delay discounting in adults receiving treatment for marijuana dependence. *Experimental and Clinical Psychopharmacology, 21*(1), 46–54. DOI: 10.1037/a0030943.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavioral Research Methods, 40*, 879–891.

Read, J., Merrill, J., Kahler, C., & Strong, D. (2007). Predicting functional outcomes among college drinkers: Reliability and predictive validity of the Young Adult Alcohol Consequences Questionnaire. *Addictive Behaviors, 32*(11), 2597–2610.

Reynolds, B., & Schiffbauer, R. (2004). Measuring state changes in human delay discounting: An experiential discounting task. *Behavioural Processes, 67*(3), 343–356. DOI: 10.1016/j.beproc.2004.06.003.

.SAMHSA, Substance Abuse and Mental Health Services Administration (2012). Results from the 2012 national survey on drug use and health. Summary of National Findings, Vol. I, (Office of Applied Studies, NSDUH Series H-38A, HHS Publication No. SMA10–4586 Findings). Rockville, MD.

Scott-Sheldon, L. J., Carey, K. B., Elliott, J. C., Garey, L., & Carey, M. P. (2014). Efficacy of alcohol interventions for first-year college students: A meta-analytic review of randomized controlled trials. *Journal of Consulting and Clinical Psychology*, *82*(2), 177–188. DOI: 10.1037/a0035192.

Skidmore, J. R., Murphy, J. G., & Martens, M. P. (2014). Behavioral economic measures of alcohol reward value as problem severity indicators in college students. *Experimental and Clinical Psychopharmacology*, *22*(3), 198–210.

Smith, A. E., Martens, M. P., Murphy, J. G., Buscemi, J., Yurasek, A. M., & Skidmore, J. (2010). Reinforcing efficacy moderates the relationship between impulsivity-related traits and alcohol use. *Experimental and Clinical Psychopharmacology*, *18*(6), 521.

Stanger, C., Ryan, S. R., Fu, H., Landes, R. D., Jones, B. A., Bickel, W. K., & Budney, A. J. (2012). Delay discounting predicts adolescent substance abuse treatment outcome. *Experimental and Clinical Psychopharmacology*, *20*(3), 205–212.

Stephens, R. S., Roffman, R. A., & Curtin, L. 2000. Comparison of extended versus brief treatments for marijuana use. *Journal of Consulting and Clinical Psychology*, *68*(5), 898.

Tabachnick, B. G. & Fidell, L. S. (2012). *Using multivariate statistics*. 6th ed. Needham Heights, MA: Allyn & Bacon.

Tucker, J. A., Roth, D. L., Vignolo, M. J., & Westfall, A. O. (2009). A behavioral economic reward index predicts drinking resolutions: Moderation revisited and compared with other outcomes. *Journal of Consulting and Clinical Psychology*, *77*, 219–228.

Tucker, J., Vuchinich, R., Black, B., & Rippens, P. (2006). Significance of a behavioral economic index of reward value in predicting drinking problem resolution. *Journal of Consulting and Clinical Psychology*, *74*(2), 317–326.

Vuchinich, R., & Simpson, C. (1998). Hyperbolic temporal discounting in social drinkers and problem drinkers. *Experimental and Clinical Psychopharmacology*, *6*(3), 292–305.

Washio, Y., Higgins, S. T., Heil, S. H., McKerchar, T. L., Badger, G. J., Skelly, J. M., & Dantona, R. L. (2011). Delay discounting is associated with treatment response among cocaine-dependent outpatients. *Experimental and clinical psychopharmacology*, *19*(3), 243.

White, A., Kraus, C., & Swartzwelder, H. (2006). Many college freshmen drink at levels far beyond the binge threshold. *Alcoholism: Clinical and Experimental Research*, *30*(6), 1006–1010.

Yoon, J. H., Higgins, S. T., Heil, S. H., Sugarbaker, R. J., Thomas, C. S., & Badger, G. J. (2007). Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. *Experimental Clinical Psychopharmacology*, *15*, 176–186.

Yurasek, A. M., Dennhardt, A. A., & Murphy, J. G. (2014). A randomized controlled trial of a behavioral economic intervention for substance abuse. Manuscript submitted for publication.

Yurasek, A. M., Murphy, J. G., Clawson, A. H., Dennhardt, A. A., & MacKillop, J. (2013). Smokers report greater demand for alcohol on a behavioral economic purchase task. *Journal of Studies on Alcohol and Drugs*, *74*(4), 626.

Received: August 1, 2014
Final Acceptance: November 16, 2014