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Delayed Reward Discounting and Alcohol Misuse: The Roles of Response Consistency and Reward Magnitude

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Abstract

Delayed reward discounting (DRD) is a common index of impulsivity that refers to an individual's devaluation of rewards based on delay of receipt and has been linked to alcohol misuse and other maladaptive behaviors. The current study investigated response consistency and reward magnitude effects in two measures of DRD in a sample of 111 undergraduates who consumed an average of 10.7 drinks/week. These variables were also examined in relation to alcohol use and misuse. Results indicated highly consistent performance on both measures of DRD, although significant differences were evident based on task parameters. There was also clear evidence of a magnitude effect on DRD. Finally, a number of significant associations between DRD and both alcohol use and misuse were found. These findings suggest that individuals possess a relatively consistent cognitive template for DRD choice preferences, but that the template systematically varies by both reward magnitude and delay length.

Keywords

Behavioral Economics; Delay Discounting; Alcohol; Response Consistency; Magnitude Effects

Introduction

Behavioral economics integrates the principles of psychology and economics to understand how individuals make transactions with the world (Bickel, et al., 2007; Camerer, 1999). This approach has been extensively applied to both normal and abnormal behavior, and has made particularly important contributions in the area of alcohol use disorders (AUDs) and other addictive behaviors (Vuchinich & Heather, 2003). One behavioral economic variable that has been extensively examined as a determinant of addiction is an individual's ability to forgo small immediate rewards to achieve larger future rewards. This process of intertemporal choice, termed delayed reward discounting (DRD), refers to the observation that the value of a delayed reinforcer is discounted (i.e., reduced in value) as a function of time to reinforcer delivery (Ainslie, 1975). Stated differently, the longer a person has to wait

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for a particular reward, the greater its value typically diminishes relative to one that is smaller but immediately available. An individual's general level of preference for smaller immediate rewards compared to larger delayed rewards is considered to be a behavioral economic measure of impulsivity (Ainslie, 1975; for a comprehensive review, see Madden & Bickel, 2009).

Alcohol misuse has consistently been associated with steeper discounting of delayed rewards (Bjork, Hommer, Grant, & Danube, 2004; Boettiger, et al., 2007; Mitchell, Fields, D'Esposito, & Boettiger, 2005; Mitchell, Tavares, Fields, D'Esposito, & Boettiger, 2007; Vuchinich & Simpson, 1998). Compared to matched control groups, steeper DRD has also been observed in individuals who are dependent on nicotine (e.g., Baker, Johnson, & Bickel, 2003), stimulants (e.g., Coffey, Gudleski, Saladin, & Brady, 2003), or opiates (e.g., Madden, Petry, Badger, & Bickel, 1997), and in pathological gamblers (e.g., MacKillop, Anderson, Castelda, Mattson, & Donovick, 2006). In addition, a number of studies have showed that individual differences in DRD prospectively predict alcohol and tobacco treatment outcomes (Krishnan-Sarin, et al., 2007; MacKillop & Kahler, 2009; Tucker, Foushee, & Black, 2008; Tucker, Vuchinich, Black, & Rippens, 2006; Tucker, Vuchinich, & Rippens, 2002; Yoon, et al., 2007). The precipitous devaluation of delayed rewards is hypothesized to underlie the repeated loss of control that characterizes addictive behavior across domains (Ainslie, 2001; Bickel & Marsch, 2001; Rachlin & Green, 1972).

The behavioral mechanism underlying loss of control is putatively a result of the generally hyperbolic nature of DRD, meaning that outcomes disproportionately gain and lose value based on their temporal proximity (Ainslie, 1975; Bickel & Marsch, 2001). Numerous studies have shown that DRD is well characterized by the following hyperbolic equation (Mazur, 1987):

$$V=A/(1+kD), \quad (1)$$

where *V* is the present discounted value of the delayed reinforcer, *A* is the amount of the delayed reinforcer, *D* is the delay to the reinforcer, and *k* is a free parameter that corresponds to the temporal discounting function. The *k* parameter reflects the index of impulsivity, with larger *k* values indicating more precipitous devaluation of a larger delayed reward. As a result, rewards precipitously lose value with the introduction of a delays and dramatically gain value as access to the reward becomes temporally close.

One consequence of hyperbolic DRD is dynamic inconsistency, or preference reversals from a larger delayed reward to a smaller immediate reward as the temporal proximity to the smaller reward gets smaller and its relative value dramatically increases. This is important because preference reversals from larger delayed rewards to smaller immediate rewards are phenomenologically similar to alcohol misuse. That is, an individual with an AUD may frequently express the desire or intention to stop or cut down on their alcohol consumption with the goal of gaining the larger delayed rewards associated with sobriety (e.g., employment, good health and family relationships), but nonetheless choose the smaller immediate rewards associated with alcohol use (e.g., stimulation, stress reduction) when alcohol becomes imminently available.

To avoid the idiosyncrasies of personal preferences, money is the most common domain-general reinforcer used in assessing DRD. Using this paradigm, although a number of studies have found significant associations between DRD and alcohol misuse, there have also been null findings and heterogeneity in effect sizes (Field, Christiansen, Cole, & Goudie, 2007; MacKillop, Mattson, Anderson Mackillop, Castelda, & Donovick, 2007; Reimers, Maylor, Stewart, & Chater, 2009; Rossow, 2008; Vuchinich & Simpson, 1998). As such, the relationship between DRD and alcohol misuse is by no means a settled scientific question. Importantly, DRD is substantially affected by several task parameters (for a review, see Odum & Baumann, 2009), and understanding the role of DRD in alcohol use and misuse may benefit from clarification of these influences.

One potentially important question that has received relatively little direct study is the extent to which DRD preferences are consistent within an assessment paradigm. In other words, do individuals possess a consistent cognitive intertemporal choice template for evaluating preferences between rewards, or are these preferences variable and fluctuating? Only a few studies have systematically evaluated response consistency within a single testing session and found that individuals were generally consistent across a range of reward magnitudes (Kirby & Marakovic, 1996; Kirby, Petry, & Bickel, 1999). However, both of these reports used a relatively brief DRD assessment (Multiple Choice Questionnaire; MCQ; Kirby et al., 1999), making it unclear whether participants would show similarly high consistency on longer and more complex measures of DRD that provide more precise estimates of temporal discounting. The potential importance of response consistency is also underscored by evidence of greater inconsistency in substance-dependent samples. Kirby et al. (1999) reported that heroin-dependent individuals had lower response consistency on the MCQ when compared to healthy controls indicating potentially meaningful differences in internal response consistency between addicted and healthy samples. To date, there has been little research on consistency of DRD in general, and no published research examining the relationship between response consistency and alcohol misuse.

Another widely-documented task parameter that affects DRD is reward magnitude. Termed the ‘magnitude effect,’ this reflects typically greater impulsivity for smaller magnitude choices. That is, people tend to be increasingly impulsive as the stakes get lower and vice versa. Several studies have found steeper discounting for smaller compared to larger rewards (e.g., Estle, Green, Myerson, & Holt, 2006; Giordano, et al., 2002; Green, Myerson, & McFadden, 1997; Kirby, 1997). As an illustrative case, Green, Myerson, and McFadden (1997) found that the degree of discounting was inversely related to the size of the delayed monetary rewards that ranged from $100 to $25,000: as the overall magnitude of rewards increased, the observed level of impulsivity decreased, even though the task parameters were proportionately identical. Magnitude effects on DRD of monetary outcomes have also been observed in substance dependent samples (e.g., Baker, et al., 2003; Giordano, et al., 2002; Kirby & Petry, 2004; Kirby, et al., 1999; MacKillop & Kahler, 2009; MacKillop, et al., 2010). Magnitude effects are also highly relevant to alcohol misuse, in which a small individual impulsive decision to have a single drink then precipitates a drinking episode, and, if repeated, summates to an AUD. Despite its relevance, however, there has been little research on what role magnitude effects play in alcohol misuse.

The current study investigated DRD response consistency and magnitude effects in relation to alcohol use and misuse. Response consistency and magnitude effects were evaluated using two DRD measures that included choices involving a range of outcome sizes. Based on the existing literature, the study had three experimental hypotheses: (a) There would be evidence of a magnitude effect in DRD (i.e., participants would show greater impulsivity for small rewards compared to large rewards); (b) Participants would generally be consistent on all DRD measures (i.e., mutually exclusive preferences expressed over the course of a task would not be contradictory); (c) Increased DRD would be positively associated with alcohol use and alcohol misuse, as measured by drinks/week and Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993), respectively. Moreover, the study sought to examine whether individual variation in terms of reward magnitude or response consistency was related to the relationship between DRD and alcohol misuse.

Method

Participants

Participants were 111 University of Georgia undergraduates (63% female) who were on average 20.8 years old (SD =3.2); 84% were White, 6% were African American, 7% were Asian, 1% were biracial, and 2% did not report race. The inclusion criteria for this study were current undergraduate status and at least 18 years of age. Although drinking history was assessed as part of this study, drinking status was not a criterion for participation in this study. Participants were compensated with either research credit or extra credit in open-enrollment psychology courses. Participants drank an average of 10.7 (SD=10.5; range 0-50) drinks/week and had a mean AUDIT score of 7.9 (SD = 5.2; range 0-21). The AUDIT scores for approximately 50% of the sample (n=53) exceeded the recommended cutoff AUDIT score of 8 that indicates potential alcohol problems (Babor, Higgins-Biddle, Saunders, & Monteiro, 2001), suggesting that this sample comprised a large proportion of hazardous drinkers.

Assessment

Demographics—Participants completed a comprehensive demographics assessment including sex, race, ethnicity, income, and other descriptive variables.

Alcohol use and alcohol-related problems—Drinks per week were calculated via the Daily Drinking Questionnaire (DDQ; Collins, Parks, & Marlatt, 1985), a seven-item measure of an individual’s alcohol consumption during a typical week during the past month. The DDQ is a widely used measure of drinking that has been shown to have good psychometric properties (Kivlahan, Marlatt, Fromme, Coppel, & Williams, 1990). The AUDIT (Saunders, et al., 1993) was used as a measure of alcohol misuse.

Monetary Choice Questionnaire—Delayed reward discounting was assessed using the MCQ (Kirby, et al., 1999), a validated self-report measure of DRD. Individuals made 27 choices between smaller immediate rewards and larger delayed rewards that were preconfigured at various levels of hyperbolic discounting. This measure provides estimates of an individual's temporal discounting of rewards at three magnitudes (small: $25-35; medium: $50-60; large: $75-85)

Delay Discounting Task—Delayed reward discounting was also assessed using a multi-item delay discounting task (DDT). Participants made choices between hypothetical smaller immediate and larger delayed monetary rewards. The large reward was $1, $10, or $100 available after one of four delays (1 day, 1 week, 1 month, or 1 year). The smaller reward was proportional to the larger reward (1%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 99%) and was available today. This resulted in a total of 132 discounting trials that were presented in a semi-randomized trial sequence that contained no adjacent trials with the same large reward magnitude or delay length. Discounting stimuli were presented via overhead projector using a Microsoft PowerPoint© slideshow with programmed slide transitions. Each trial was displayed for 6 s, followed by a 2 s fixation cross. The 6 s choice duration was chosen based on previous intertemporal choice paradigms (e.g., Bickel et al., 2009) and behavioral pilot testing on a separate sample of undergraduate students to determine a comfortable choice duration. On each trial, participants were asked if they would rather have the larger or smaller amount, with the right-left position of the two options randomized across trials. The two options on the screen were labeled as A or B and participants indicated their choices by checking a box next to the corresponding letter on a paper-based response sheet. Participants were given brief 15 s breaks after every 25 trials resulting in a total paradigm time of 18 m and 51 s.

Data Analysis

All variables were initially screened for missing data, outliers (Zs > 3.29), and distribution abnormalities (Tabachnick & Fidell, 2001). For the DDT, indifference points for each of the four delay lengths were calculated based on each participant's array of responses within the three magnitudes. Potential indifference points were operationally defined as the average of small reward values. Specifically, participants were assigned indifference points reflecting the highest consistency among potential indifference points or the arithmetic mean of two or more values that were equally consistent. In addition to using this consistency measure to define indifference points, this value was also used as the primary dependent measure of response consistency on the DDT (see below). The hyperbolic discount function (see equation 1) was then fit to the discount curves for each magnitude (Mazur, 1987). We also characterized the empirical proportionate discounting level via area under the discounting curve (AUC; Myerson, Green, & Warusawitharana, 2001). Proportionate AUC values were generated for each magnitude using GraphPad Prism 5 software. Responses from the MCQ were analyzed using the approach described by Kirby et al. (1999). Hyperbolic discounting functions (i.e., k) were estimated based on each participant's array of responses within the three magnitudes and an overall discounting function was calculated by taking the geometric mean of these three k values. Participants were assigned a k value reflecting the highest consistency among the discounting values or the geometric mean of multiple k values that were equally consistent (Kirby et al., 1999).

Response consistency on both the DDT and MCQ was quantified using the approach described in Kirby et al. (1999). For the MCQ, this refers to the number of responses consistent with the best fitting k value. For the DDT, this refers to the percentage of consistent responses relative to the ascertained point of indifference within an array of items (i.e., a delay interval by reward magnitude). In both cases, consistency was reflected as a percentage, with 100% indicating perfect consistency.

A within-subjects ANOVA was used to examine response consistency on the DDT and MCQ. The presence of magnitude effects on the DDT and MCQ (i.e., greater discounting for smaller rewards compared to larger rewards) was examined using within-subjects analysis of variance (ANOVA). Finally, Pearson's product-moment correlations were used to examine the continuous relationships among variables. All analyses were conducted using SPSS Version 17.0, using a conventional α level of .05 for statistical significance in all analyses and an effect size of η_p^2.

Results

Preliminary Analyses

Two participants did not complete the DDQ, one participant did not complete the AUDIT, and three participants did not provide complete data on the MCQ. This resulted in a final *n* of 105 participants with complete data. No outliers were observed according to the criteria outlined in Tabachnick & Fidell (2001). Examination of the distribution histograms for *k* values on DDT and MCQ showed evidence of positive skew and these variables were logarithmically transformed. This transformation improved the distributions for k values on the MCQ, with non-significant levels of skewness and kurtosis for all variables except skewness for small magnitude choices (Z = 4.2, $p < .01$). The transformation did not improve the distributions for *k* values on the DDT. As a result, subsequent analyses for the DDT were conducted using AUC values instead of *k* values. Of note, *k* values and AUC values were highly correlated (*r*s > .95, $p < .001$).

Primary Analyses

Mean response consistency (+/− 1 SE) by magnitude and delay length on the DDT is shown in Figure 1. Participants were generally highly consistent in absolute terms across delays and reward magnitudes (M consistency = 96.1%, SE = 0.2%). Consistency was analyzed using a magnitude ($100, $10, $1) × delay length (1 day, 1 week, 1 month, 1 year) ANOVA. This analysis revealed significant main effects of magnitude, $F(2, 208) = 30.1$, $p < .001$, $\eta_p^2 = .22$, and delay, $F(3, 312) = 23.2$, $p < .001$, $\eta_p^2 = .18$, as well as a significant interaction, $F(6, 624) = 3.9$, $p < .05$, $\eta_p^2 = .04$. Participants showed the highest consistency for larger rewards at shorter delays. Examination of the curves in Figure 1 indicated that consistency for $100 was high (> 98%) from 1 day to 1 month and then dropped significantly at 1 year, nonetheless remaining high in absolute consistency. Response consistency for $1 showed an opposite pattern, with initially high consistency at 1 day (98%), dropping to below 94% thereafter.

Participants were highly consistent across all three reward magnitudes on the MCQ (small M = 99.2%, SE = 0.3%; medium M = 98.9%, SE = 0.3%; large M = 99.0%, SE = 0.3%).

Contrary to the findings on the DDT, consistency on the MCQ did not significantly differ between reward magnitudes, $F(2,208) = 0.1$, $p = 0.87$, $\eta_p^2 = .001$.

A within-subjects ANOVA was conducted to examine the effect of monetary reward magnitude on DRD. For AUC values from the DDT, this analysis revealed a significant main effect of magnitude, $F(2, 208) = 73.8$, $p < .001$, $\eta_p^2 = .42$ (Table 1). Participants were least impulsive for choices for $100 compared to the two smaller magnitudes ($p < .001$), but AUC did not differ between $10 and $1 ($p > .10$). Correlations among AUC values for the three magnitudes were statistically significant (*r*s > .65; Table 2). The presence of a magnitude effect on the MCQ was similarly examined using a within-subjects ANOVA, which revealed a significant main effect of magnitude, $F(2, 208) = 121.9$, $p < .001$, $\eta_p^2 = .54$. Participants were least impulsive for large rewards, followed by medium and then small rewards, with all three magnitudes differing significantly ($p < .001$). Correlations among the three magnitudes of discounting on the MCQ were high (*r*s > .82; Table 2).

Pearson’s product-moment correlations were conducted in the entire sample to examine continuous relationships between DRD and drinking variables (see Table 2). Significant associations were evident between the two drinking variables and, for both, with large and small discounting on the MCQ, but not the DDT. Consistency on the MCQ and the DDT was not significantly associated with drinks/week or AUDIT scores (all *p*s >.10).

Discussion

This study sought to characterize performance consistency and magnitude effects on two measures of DRD, and to investigate the relationships between these variables and measures of alcohol use and misuse. Across both measures of DRD, participants exhibited generally high consistency (~95-99%), though consistency on the DDT was significantly influenced by both delay length and reward magnitude. In that case, main effects revealed that participants were relatively less consistent about choices that were more temporally distant and smaller in magnitude, and an interaction revealed that decrements in consistency were present at shorter delays for choices involving smaller rewards. In absolute terms, however, the level of consistency was nonetheless high, and there were no significant associations between consistency of performance and alcohol use variables. With regard to the effect of reward magnitude on DRD, consistent with predictions, the results revealed significant magnitude effects (i.e., steeper discounting for small compared to large magnitude rewards) on both the MCQ and DDT. A number of significant associations between discounting rate and alcohol variables were also observed. Specifically, greater alcohol consumption was associated with steeper discounting of large and small rewards on the MCQ. Significant correlations with alcohol misuse (assessed by the AUDIT) were likewise observed for discounting rates at those magnitudes on the MCQ.

These findings contribute to the accumulating literature on DRD and alcohol misuse in a number of ways. First, the current study provides clear evidence that participants’ DRD preferences were highly consistent in both simple and complex DRD paradigms. The finding that participants showed highly consistent performance across multiple measures of DRD corroborates the small number of previous studies that have examined within-task response coherence (Kirby & Marakovic, 1996; Kirby, et al., 1999). This further supports the notion that the observed temporal discounting functions are not a result of fluctuating or inconsistent cognitive preferences. Rather, individuals appear to possess a generally consistent cognitive template for evaluating intertemporal choice preferences within a given paradigm. Moreover, the current study examined the relationship between consistency and alcohol use, finding no relationship, and suggesting that high internal coherence of preferences is a general property and not a possible mechanism for the relationship between DRD and alcohol use. Given that this is only one study, it would be premature to conclude definitively that consistency of intertemporal choice preferences are not associated with alcohol involvement, but the current findings do not suggest that this is the case.

Of note, although absolute consistency was high, it did vary according to the DRD measures employed. Consistency was equally high across all magnitudes on the MCQ, which is in line with previous reports (Kirby & Marakovic, 1996; Kirby, et al., 1999). Response consistency on the DDT did vary as a function of both delay and reward magnitude. First, response consistency increased as a function of reward magnitude. This greater consistency for larger rewards may be explained by considering the incentive salience of the rewards. Specifically, it is plausible that $1 and $10 were viewed as trivial (i.e. of lower salience) compared to $100, and therefore it was more likely for participants to have inconsistent preferences for the smaller rewards. Second, response consistency decreased with increasing delay lengths. This finding may be interpreted in the context of temporal proximity of rewards, whereby participants generally do not have to make many decisions between outcomes that are temporally distant (i.e., one year in the future) and as a result their template for evaluating these choices may be more variable. Significant differences in response consistency on the DDT, but not the MCQ, may reflect parametric differences between the two DRD measures. The MCQ is relatively brief, both in terms of the number of choices (27 items) and the time required to complete the questionnaire (typically < 5 minutes). The DDT used in this study, on the other hand, was more complex, requiring participants to make many more choices (110 items) over a much longer duration (~19 minutes). Another important distinction between these two measures is that on the MCQ, participants were presented with all choices simultaneously whereas on the DDT, choices were presented individually. Therefore, it is plausible that the structure of the MCQ provided an artificially stable context for decision making resulting in nearly perfect consistency. Since participants were only shown one trial at a time on the DDT, it may be that participants had to rely more heavily on an internal choice template and maintain that template across a longer period of time when making their decisions.

A second important contribution of the current study related to the findings pertaining to magnitude effects in discounting. Consistent with previous studies (Baker, et al., 2003; Estle, et al., 2006; Giordano, et al., 2002; Green, et al., 1997; Kirby, 1997; Kirby & Marakovic, 1996; MacKillop, et al., 2010), participants showed significantly steeper discounting of smaller rewards compared to larger ones. These magnitude effects were observed on both the MCQ and the DDT, however, to differing extents. As was predicted from previous work (e.g., Kirby & Marakovic, 1996; Kirby, et al., 1999), *k* values were significantly different across all three reward magnitudes on the MCQ—a result that has also been reported in AUD samples (Kirby & Petry, 2004; MacKillop, et al., 2010). When DRD was assessed via the DDT, however, AUC values were significantly higher for $100 compared to both $10 and $1, but the latter two magnitudes did not significantly differ. This is not to say that the MCQ is more sensitive to magnitude effects, but instead that the lack of significant differences across all three magnitudes on the DDT may be a consequence of the specific dollar amounts used. Specifically, it is plausible that $10 and $1 were effectively both categorized by participants as relatively trivial rewards, which is consistent with the pattern of findings relating to a medium magnitude reward in a study by Giordano et al. (2002). In that study, similar discounting rates were evident between the small and medium-sized rewards.

Most important, however, was evidence that significant associations between DRD and alcohol use appeared to be specific to certain reward magnitudes. Specifically, although all correlations were directionally consistent with greater impulsivity being associated with greater alcohol use, the associations were only significant for discounting of large and small magnitude rewards for the MCQ. This suggests that certain task parameters – specifically, reward magnitudes – assay the underlying alcohol-related cognitive processes with higher resolution and in doing so, bring these associations into sharper relief. These differences are important because discounting at different magnitudes of reward tend to be significantly correlated, which could be misinterpreted as suggesting variants of discounting tasks are essentially equivalent. The current study illustrates that this may not be the case and although relative impulsivity may correspond across tasks, the differences across tasks are important and, given the diversity of tasks used, these differences may be responsible for some of the mixed findings in the literature. That is, different task parameters of DRD paradigms differentially recruit the underlying cognitive templates and neurobiological substrates that overlap in both DRD decision making and alcohol misuse and, as a result, vary in the resolution of this overlap. Finally, although beyond the scope of the current study, identifying the task parameters that optimize the resolution of the relationship between discounting behavior and alcohol use has the potential to provide insights into the nature of the underlying cognitive structures being tapped. For instance, assessing the relationship between alcohol misuse and DRD across a larger range of reward magnitudes (e.g., Green, et al., 1997) may be particularly informative.

A final implication of the present study relates to clinical interventions for substance use disorders and other maladaptive behaviors associated with precipitous DRD (e.g., pathological gambling). Impulsive DRD has been shown to be a negative prognostic factor for treatment success in alcohol misuse (Tucker, et al., 2008; Tucker, et al., 2006; Tucker, et al., 2002) and smoking (Krishnan-Sarin, et al., 2007; MacKillop & Kahler, 2009; Yoon, et al., 2007). To date, three different interventions designed to reduce impulsive DRD have shown promise with smokers and stimulant dependent individuals (Bickel, Yi, Landes, Hill, & Baxter, 2011; Black & Rosen, 2011; Hofmeyr, Ainslie, Charlton, & Ross, 2011), suggesting that DRD may be a potential treatment target. The present findings indicate that DRD is highly consistent within individuals and supports the notion that any interventions that affect DRD and produce downstream improvement in clinical status would not likely be due to inconsistencies in DRD in the individuals.

These findings should be interpreted in the context of the study's strengths and weaknesses. Strengths include use of multiple measures to assess DRD across a range of delay intervals and reward magnitudes and the use of validated measures of alcohol use and misuse. One potential limitation of this study was the use of hypothetical DRD measures, though several studies have found close correspondence between discounting of hypothetical and actual monetary rewards (Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003). Nonetheless, it is possible that using actual monetary rewards would have revealed different results. The DDT used in this study was also longer and more complex than other DRD measures used in previous research. In addition, while the sample in this study was moderately large, it is worth noting that the participants were all college students and primarily white young adults. The rate of DRD is known to be inversely related to age, with younger participants typically exhibiting steeper DRD compared to older ones (Green, Fry, & Myerson, 1994). An interesting empirical question that could not be addressed here but follows from the present study is whether associations between alcohol misuse and various indices of DRD vary systematically by age. In addition, given the pattern of correlations, it appears the study would have been likely to detect significant correlations if the sample size were somewhat larger. This presumes the effect sizes would have remained the same and, as such, does not alter the conclusions with regard to the importance of reward magnitude. It does, however, suggest the study was somewhat underpowered. A further consideration is the study's cross-sectional design, which precludes definitive conclusions about the causal relationship among alcohol-related variables and DRD. Although it is plausible that DRD constitutes an etiological factor in the development of alcohol misuse, these data cannot address directly address whether DRD is an antecedent or consequence. In sum, caution should be exercised in generalizing these findings to other populations, particularly in the case of the lack of associations between DRD consistency and alcohol misuse.

A methodological consideration that is also a unique contribution of the study was the use of a presentation format in the DDT. This approach has not been used previously (to our knowledge); however, there are several reasons to support its validity in this study. The task itself used parameters that were highly similar to individual DDT assessment and the timing was congruent with past individual DDT studies (e.g., Bickel et al., 2009). In addition, the high rates of consistency and prototypic data suggest this is a viable approach. However, there was no direct comparison between this approach and a standard DDT, so it is not possible to determine whether any aspect of this assessment played a role. Conservatively, these results provisionally support this approach and future studies comparing the two will be necessary to definitively demonstrated equivalence or method-specific influences.

A final important consideration is that the current results could be interpreted as suggesting that the MCQ is a more sensitive measure of DRD in the context of alcohol misuse. However, a more conservative interpretation would hold that rather than favoring one assessment type over another, the data suggest that certain magnitudes are specifically important. Although discounting on the DDT was not significantly correlated with alcohol use, the same was true for the medium magnitude MCQ scale, suggesting the difference was magnitude specific not task specific. Although the MCQ has a number of strengths, especially its brevity, a full DDT assessment provides a much more precise estimate of an individual temporal discounting function. Further, a DDT generates data that can be characterized using several analytic approaches, as opposed to the MCQ, which is based on a *k*-based analytic strategy. Finally, there is also some evidence that the MCQ has not been sensitive to population differences that have been documented with DDT paradigms (e.g., Kirby & Petry, 2004; Madden, Petry, & Johnson, 2009), which may be a function of its lack of precision. Taken together, these findings underscore the importance of task parameters, but do not specifically support the superiority of one measure over another.

In conclusion, this study investigated DRD response consistency and magnitude effects in relation to alcohol use and misuse. The hypotheses were largely supported, particularly in that individuals showed highly consistent DRD performance across a range of tasks and that individuals discounted small rewards to a greater extent than large rewards. However, the results also indicated that consistency was affected by both incentive salience and temporal proximity of rewards. Lastly, more impulsive DRD was associated with alcohol use and misuse, but these associations were specific to certain reward magnitudes. These findings extend the existing literature in a number of ways and suggest strategies for clarifying the relationships between DRD and alcohol misuse, and, ultimately, informing intervention strategies.

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References

Ainslie G. Specious reward: a behavioral theory of impulsiveness and impulse control. Psychol Bull. 1975; 82(4):463–496. [PubMed: 1099599]

Ainslie, G. Breakdown of Will. Cambridge University Press; Cambridge: 2001.

Babor, TF.; Higgins-Biddle, JC.; Saunders, JB.; Monteiro, MG., editors. AUDIT: The Alcohol Use Disorders Identification Test: Guidelines for Use in Primary Care. Second Edition. World Health Organization; Geneva, Switzerland: 2001. WHO Document No. WHO/MSD/MSB/01.6a

Baker F, Johnson MW, Bickel WK. Delay discounting in current and never-before cigarette smokers: similarities and differences across commodity, sign, and magnitude. J Abnorm Psychol. 2003; 112(3):382–392. [PubMed: 12943017]

Bickel WK, Marsch LA. Toward a behavioral economic understanding of drug dependence: delay discounting processes. Addiction. 2001; 96(1):73–86. [PubMed: 11177521]

Bickel WK, Miller ML, Yi R, Kowal BP, Lindquist DM, Pitcock JA. Behavioral and neuroeconomics of drug addiction: competing neural systems and temporal discounting processes. Drug Alcohol Depend. 2007; 90(Suppl 1):S85–91. [PubMed: 17101239]

Bickel WK, Yi R, Landes RD, Hill PF, Baxter C. Remember the future: working memory training decreases delay discounting among stimulant addicts. Biol Psychiatry. 2011; 69(3):260–265. [PubMed: 20965498]

Bjork JM, Hommer DW, Grant SJ, Danube C. Impulsivity in abstinent alcohol-dependent patients: relation to control subjects and type 1-/type 2-like traits. Alcohol. 2004; 34(2-3):133–150. [PubMed: 15902907]

Black AC, Rosen MI. A money management-based substance use treatment increases valuation of future rewards. Addict Behav. 2011; 36(1-2):125–128. [PubMed: 20826055]

Boettiger CA, Mitchell JM, Tavares VC, Robertson M, Joslyn G, D'Esposito M, et al. Immediate reward bias in humans: fronto-parietal networks and a role for the catechol-O-methyltransferase 158(Val/Val) genotype. J Neurosci. 2007; 27(52):14383–14391. [PubMed: 18160646]

Camerer C. Behavioral economics: reunifying psychology and economics. Proc Natl Acad Sci U S A. 1999; 96(19):10575–10577. [PubMed: 10485865]

Coffey SF, Gudleski GD, Saladin ME, Brady KT. Impulsivity and rapid discounting of delayed hypothetical rewards in cocaine-dependent individuals. Exp Clin Psychopharmacol. 2003; 11(1): 18–25. [PubMed: 12622340]

Collins RL, Parks GA, Marlatt GA. Social determinants of alcohol consumption: The effects of scoial interaction and model status on the self-administration of alcohol. Journal of Consulting and Clinical Psychology. 1985; 53:189–200. [PubMed: 3998247]

Estle SJ, Green L, Myerson J, Holt DD. Differential effects of amount on temporal and probability discounting of gains and losses. Mem Cognit. 2006; 34(4):914–928.

Field M, Christiansen P, Cole J, Goudie A. Delay discounting and the alcohol Stroop in heavy drinking adolescents. Addiction. 2007; 102(4):579–586. [PubMed: 17309540]

Giordano LA, Bickel WK, Loewenstein G, Jacobs EA, Marsch L, Badger GJ. Mild opioid deprivation increases the degree that opioid-dependent outpatients discount delayed heroin and money. Psychopharmacology (Berl). 2002; 163(2):174–182. [PubMed: 12202964]

Green L, Fry AF, Myerson J. Discounting of delayed rewards: A life-span comparison. Psychological Science. 1994; 5(1):33–36.

Green L, Myerson J, McFadden E. Rate of temporal discounting decreases with amount of reward. Memory and Cognition. 1997; 25:715–723. [PubMed: 9337589]

Hofmeyr A, Ainslie G, Charlton R, Ross D. The relationship between addiction and reward bundling: an experiment comparing smokers and non-smokers. Addiction. 2011; 106(2):402–409. [PubMed: 20955491]

Johnson MW, Bickel WK. Within-subject comparison of real and hypothetical money rewards in delay discounting. J Exp Anal Behav. 2002; 77(2):129–146. [PubMed: 11936247]

Kirby KN. Bidding on the future: Evidence against normative discounting of delayed rewards. Journal of Experimental Psychology: General. 1997; 126(1):54–70.

Kirby KN, Marakovic NN. Delay-discounting probabilistic rewards: Rates decrease as amounts increase. Psychonomic Bulletin & Review. 1996; 9(1):100–104. [PubMed: 24214810]

Kirby KN, Petry NM. Heroin and cocaine abusers have higher discount rates for delayed rewards than alcoholics or non-drug-using controls. Addiction. 2004; 99(4):461–471. [PubMed: 15049746]

Kirby KN, Petry NM, Bickel WK. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. J Exp Psychol Gen. 1999; 128(1):78–87. [PubMed: 10100392]

Kivlahan DR, Marlatt GA, Fromme K, Coppel DB, Williams E. Secondary prevention with college drinkers: Evaluation of an alcohol skills training program. Journal of Consulting and Clinical Psychology. 1990; 58:805–810. [PubMed: 2292630]

Krishnan-Sarin S, Reynolds B, Duhig AM, Smith A, Liss T, McFetridge A, et al. Behavioral impulsivity predicts treatment outcome in a smoking cessation program for adolescent smokers. Drug Alcohol Depend. 2007; 88(1):79–82. [PubMed: 17049754]

MacKillop J, Anderson EJ, Castelda BA, Mattson RE, Donovick PJ. Divergent validity of measures of cognitive distortions, impulsivity, and time perspective in pathological gambling. J Gambl Stud. 2006; 22(3):339–354. [PubMed: 16826455]

MacKillop J, Kahler CW. Delayed reward discounting predicts treatment response for heavy drinkers receiving smoking cessation treatment. Drug Alcohol Depend. 2009; 104(3):197–203. [PubMed: 19570621]

MacKillop J, Mattson RE, Anderson Mackillop EJ, Castelda BA, Donovick PJ. Multidimensional assessment of impulsivity in undergraduate hazardous drinkers and controls. J Stud Alcohol Drugs. 2007; 68(6):785–788. [PubMed: 17960295]

MacKillop J, Monti PM, Murphy JG, Miranda R, Ray L, Rohsenow DJ, et al. Alcohol demand, delayed reward discounting, and craving in relation to drinking and alcohol use disorders. Journal of Abnormal Psychology. 2010; 119(1):106–114. [PubMed: 20141247]

Madden GJ, Begotka AM, Raiff BR, Kastern LL. Delay discounting of real and hypothetical rewards. Exp Clin Psychopharmacol. 2003; 11(2):139–145. [PubMed: 12755458]

Madden, GJ.; Bickel, WK., editors. Impulsivity: The Behavioral and Neurological Science of Discounting. American Psychological Association; Washington, D.C.: 2009.

Madden GJ, Petry NM, Badger GJ, Bickel WK. Impulsive and self-control choices in opioid-dependent patients and non-drug-using control participants: drug and monetary rewards. Exp Clin Psychopharmacol. 1997; 5(3):256–262. [PubMed: 9260073]

Madden GJ, Petry NM, Johnson PS. Pathological gamblers discount probabilistic rewards less steeply than matched controls. Exp Clin Psychopharmacol. 2009; 17(5):283–290. [PubMed: 19803627]

Mazur, JE. An adjusting procedure for styding delayed reinforcement. In: Commons, ML.; Mazur, JE.; Nevin, JA.; Rachlin, H., editors. Quantitative Analysis of Behavior: Vol 5. The Effects of Delay and Intervening Events on Reinforcement Value. Erlbaum; Hillsdale, New Jersey: 1987. p. 55-73.

Mitchell JM, Fields HL, D'Esposito M, Boettiger CA. Impulsive responding in alcoholics. Alcohol Clin Exp Res. 2005; 29(12):2158–2169. [PubMed: 16385186]

Mitchell JM, Tavares VC, Fields HL, D'Esposito M, Boettiger CA. Endogenous opioid blockade and impulsive responding in alcoholics and healthy controls. Neuropsychopharmacology. 2007; 32(2): 439–449. [PubMed: 17047667]

Myerson J, Green L, Warusawitharana M. Area under the curve as a measure of discounting. Journal of Experimental Analysis of Behavior. 2001; 76(2):235–243.

Odum, AL.; Baumann, AAL. Delay discounting: State and trait variable. In: Madden, GJ.; Bickel, WK., editors. Impulsivity: The Behavioral and Neurological Science of Discounting. American Psychological Association; Washington, D.C.: 2009.

Rachlin H, Green L. Commitment, choice and self-control. J Exp Anal Behav. 1972; 17(1):15–22. [PubMed: 16811561]

Reimers S, Maylor EA, Stewart N, Chater N. Associations between a one-shot delay discounting measure and age, income, education, and real-world impulsive behavior. Personality and Individual Differences. 2009; 47:973–978.

Rossow I. Alcohol consumption and discounting. Addiction Research and Theory. 2008; 16(6):572–584.

Saunders JB, Aasland OG, Babor TF, de la Fuente JR, Grant M. Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption. II. Addiction. 1993; 88:791–804. [PubMed: 8329970]

Tabachnick, BG.; Fidell, LS. Using Multivariate Statistics. 4th ed.. Allyn & Bacon; Needham Heights, MA: 2001.

Tucker JA, Foushee HR, Black BC. Behavioral economic analysis of natural resolution of drinking problems using IVR self-monitoring. Exp Clin Psychopharmacol. 2008; 16(4):332–340. [PubMed: 18729688]

Tucker JA, Vuchinich RE, Black BC, Rippens PD. Significance of a behavioral economic index of reward value in predicting drinking problem resolution. J Consult Clin Psychol. 2006; 74(2):317–326. [PubMed: 16649876]

Tucker JA, Vuchinich RE, Rippens PD. Predicting natural resolution of alcohol-related problems: a prospective behavioral economic analysis. Exp Clin Psychopharmacol. 2002; 10(3):248–257. [PubMed: 12233985]

Vuchinich, RE.; Heather, N., editors. Choice, Behavioural Economics and Addiction. Elsevier; Amsterdam: 2003.

Vuchinich RE, Simpson CA. Hyperbolic temporal discounting in social drinkers and problem drinkers. Exp Clin Psychopharmacol. 1998; 6(3):292–305. [PubMed: 9725113]

Yoon JH, Higgins ST, Heil SH, Sugarbaker RJ, Thomas CS, Badger GJ. Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. Exp Clin Psychopharmacol. 2007; 15(2):176–186. [PubMed: 17469941]

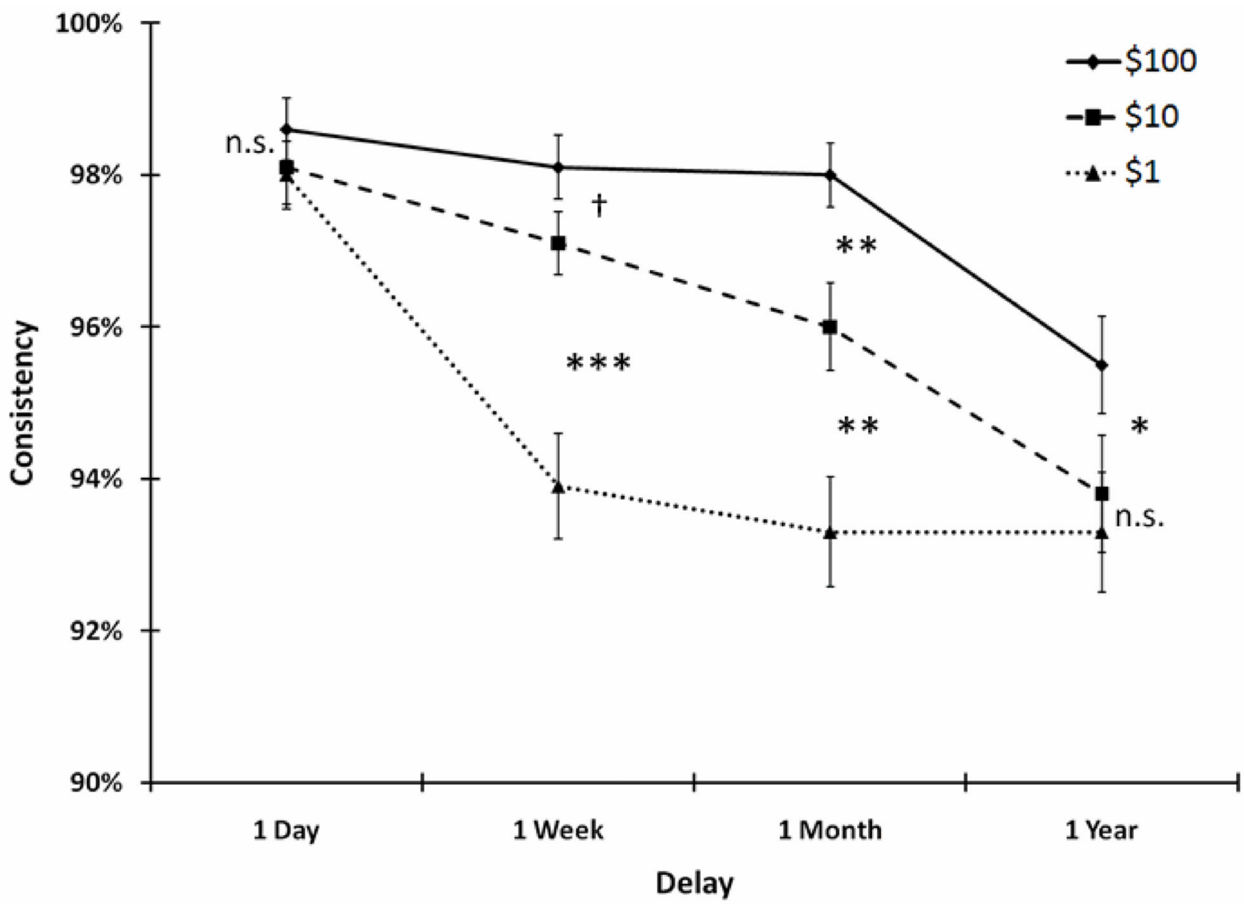

Figure 1.

Consistency of delayed reward discounting on the DDT by delay length for $100 (solid line), $10 (dashed line), and $1 (dotted line). Random responding equals 50% consistency. Data points represent mean consistency +/− 1 standard error. Note. ***$p < .001$; **$p<.01$; *$p<.05$; †$p=.051$

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Table 1

Magnitude Effects on Delayed Reward Discounting

	DDT-$100	DDT-$10	DDT-$1	$F_{(2,208)}$	η_p^2
AUC	0.70(0.022)	0.50 (0.023)	0.49 (0.028)	73.8***	.42
	MCQ-Large [$80]	**MCQ-Med [$55]**	**MCQ-Small [$30]**	$F_{(2,208)}$	η_p^2
k	0.02 (0.004)	0.03 (0.004)	0.05 (0.004)	121.9***	.54

Note. *n*=105; *AUC*, Proportionate area under the discounting curve (maximum = 1.0); *DDT*, Delay Discounting Task; *MCQ*, Multiple Choice Questionnaire; Values reflect mean (standard error); *k* values were reverse logarithmically transformed for illustration; Mean reward amounts for each MCQ magnitude are also shown in brackets;

*** $p<.001$.

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Table 2

Correlations among Delayed Reward Discounting and Alcohol-Related Variables

Variable	1	2	3	4	5	6	7	8
1. DDT-$100 AUC	–							
2. DDT-$10 AUC	.85**	–						
3. DDT-$1 AUC	.58**	.73**	–					
4. MCQ-Large [$80] k	−.65**	−.65**	−.45**	–				
5. MCQ-Med [$55] k	−.71**	−.71**	−.56**	.85**	–			
6. MCQ-Small [$30] k	−.70**	−.70**	−.52**	.82**	.86**	–		
7. Drinks / week	−.16	−.16	.05	.24**	.16	.26**	–	
8. AUDIT	−.10	−.13	−.03	.22*	.18	.27**	.68**	–

Note. *n*=105; AUC, Proportionate area under the discounting curve (maximum = 1.0); *AUDIT*, Alcohol Use Disorders Identification Test; *DDT*, Delay discounting task; *MCQ*, Multiple Choice Questionnaire; Mean reward amounts for each MCQ magnitude are also shown in brackets;

** p<.01;

* p<.05.