Published in final edited form as:

Psychol Rec. 2017 June ; 67(2): 285–292. doi:10.1007/s40732-017-0245-0.

Cross-commodity delay discounting of alcohol and money in alcohol users

Lara N. Moody^{1,2}, Allison N. Tegge^{1,3}, and Warren K. Bickel^{1,2}

¹Addiction Recovery Research Center, Virginia Tech Carilion Research Institute, Roanoke, VA, USA

²Virginia Tech, Department of Psychology, Blacksburg, VA, USA

³Virginia Tech, Department of Statistics, Blacksburg, VA, USA

Abstract

Despite real-world implications, the pattern of delay discounting in alcohol users when the commodities now and later differ has not been well characterized. In this study, 60 participants on Amazon's Mechanical Turk completed the Alcohol Use Disorder Identification Test (AUDIT) to assess severity of use and completed four delay discounting tasks between hypothetical, equivalent amounts of alcohol and money available at five delays. The tasks included two cross-commodity (alcohol now-money later and money now-alcohol later) and two same-commodity (money now-money later and alcohol now-alcohol later) conditions. Delay discounting was significantly associated with clinical cutoffs of the AUDIT for both of the cross-commodity conditions but not for either of the same-commodity delay discounting tasks. The cross-commodity discounting conditions were related to severity of use wherein heavy users discounted future alcohol less and future money more. The change in direction of the discounting effect was dependent on the commodity that was distally available suggesting a distinctive pattern of discounting across commodities when comparing light and heavy alcohol users.

Keywords

Delay discounting; alcohol use; cross-commodity; competing neurobehavioral decision system

Introduction

Alcohol use is a major contributing factor to preventable morbidity and mortality in the United States (N. B. Johnson et al., 2014; Stahre, Roeber, Kanny, Brewer, & Zhang, 2014). The Centers for Disease Control and Prevention (CDC) estimate the economic cost of

Corresponding author: Warren K. Bickel, Ph.D., Director, Addiction Recovery Research Center, Virginia Tech Carilion Research Institute, Professor of Psychology, Neuroscience, and Health Science, Virginia Tech, Professor of Psychiatry, Virginia Tech Carilion School of Medicine, 2 Riverside Circle, Roanoke, VA 24016, USA, wkbickel@vtc.vt.edu.

Conflict of Interest: LNM, LMP, WKB have no conflicts of interest to report.

Ethical approval: All procedure performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

alcohol use in the United States to be \$249 billion (Sacks, Gonzales, Bouchery, Tomedi, & Brewer, 2015). The study of intertemporal choice has provided valuable insights into the characterization of addictive disorders including alcohol use disorder (MacKillop, 2016). Studies of intertemporal choice, or delay discounting, show excessive valuation of more proximal rewards and steeper discounting of more distal rewards compared to healthy controls (Kirby, Petry, & Bickel, 1999; Petry, 2001). Most often, excessive valuation is assessed with the same reinforcer available both now and later. This same-commodity delay discounting is usually done with money as the reinforcer (MacKillop et al., 2011). Less frequently, other commodities have been employed in the same-commodity discounting paradigm (e.g., drug now, drug later; health consequences now, health consequences later; see M. W. Johnson et al., 2010; M. W. Johnson, Bickel, & Baker, 2007; Weatherly, Terrell, & Derenne, 2010). In these same-commodity delay discounting investigations, substances of abuse are consistently discounted more than money even when the amount of drug selected is equivalent in cost to the money option. For example, marijuana users discounted marijuana (M. W. Johnson et al., 2010), alcohol users discounted alcohol (Petry, 2001) and cocaine users discounted cocaine (Bickel et al., 2011) more than money.

Despite the convergent findings that substances are discounted more than money in same-commodity choice paradigms, few studies have assessed the choice patterns in cross-commodity discounting tasks (e.g., Bickel et al., 2011; Mitchell, 2004; Yoon, Higgins, Bradstreet, Badger, & Thomas, 2009) in which the reinforcers now and later differ and individuals are asked to choose between varying amounts of commodities at varying timepoints. Cross-commodity discounting speaks to the dynamic choices an individual is faced with in more naturalistic settings, as most real-world choices necessitate selecting between alternative commodities (e.g., commodity now vs. savings later). Understanding the characteristics of these choices can provide insight into how substance users navigate intertemporal and cross-commodity decisions and may illustrate opportunities to change unhealthy decision-making structures that contribute to the maintenance of addictions.

Here, we endeavor to understand how alcohol users value alcohol as compared with money across same- and cross-commodity delay discounting choice conditions. To the best of our knowledge, four previous studies have looked at cross-commodity discounting of substances of abuse. Two of these studies evaluated the preferences of cigarette smokers for cigarettes now and money later while the others looked at preferences for cocaine and money in cocaine users. The cigarette cross-commodity discounting tasks evaluated preference for equivalent values of cigarettes now versus money later in cigarettes smokers who abstained from smoking for one day (Mitchell, 2004) or one and two weeks (Yoon et al., 2009) compared to baseline delay discounting. One day of cigarette deprivation increased preference for immediately available cigarettes over a larger amount of money later while having no effect on preference for immediately available money compared to a larger amount of money available at a delay (Mitchell, 2004). However, prolonged abstinence from cigarettes of one or two weeks compared to one day of abstinence showed increased preference for delayed money over immediate cigarettes at both timepoints (Yoon et al., 2009). Importantly, these studies only investigated cross-commodity choice preferences when the substance (i.e., cigarettes) was immediately available, thus these studies do not speak to choice preferences when the substance is the delayed option. In contrast, Bickel et

al. (2011) evaluated all combinations of money and cocaine in cocaine-dependent individuals, that is response patterns for same-commodity (money now, money later and cocaine now, cocaine later) options in addition to both cross-commodity conditions (money now, cocaine later and cocaine now, money later). The greatest preference for immediacy was observed in the money now, cocaine later condition while the greatest preference for a larger delayed options was observed in the money now, money later condition. Wesley et al. (2014) extended on these findings with the addition of community controls and found that cocaine users discount both same-commodity tasks in addition to the cross-commodity cocaine now-money later task more than controls, however, no significant difference was found between money now-cocaine later discounting. Together, previous work on cross-commodity discounting of substances of abuse has provided necessary information about the acute effects of deprivation with regard to increases in impulsivity specific to the substance of abuse followed by an apparent increase in self-control and preference for delayed options once more sustained abstinence was achieved. Here we extend upon previous work to assess cross-commodity choice patterns among alcohol users.

Methods

Participants

Participants were recruited on Amazon's Mechanical Turk (MTurk; www.mturk.com), an online recruitment and data collection service where researchers can post “Human Intelligence Tasks” (HITs), which are tasks that can be completed by a computer (Paolacci & Chandler, 2014). As a platform for collecting data in research, MTurk provides several benefits compared to in-person laboratory studies, including that it is time-efficient and cost-effective. Recently, researchers have used MTurk as a way to recruit participants to complete computer-based tasks (McKerchar & Mazur, 2016; Mellis, Woodford, Stein, & Bickel, 2017; Meredith, Sweeney, Johnson, Johnson, & Griffiths, 2016; Reed, Becirevic, Atchley, Kaplan, & Liese, 2016). Qualifications for the present HIT were that the MTurk worker live in the United States and have a HIT approval rating of at least 90%. MTurk workers were compensated \$2 for completing the tasks described below, plus another \$3 if the resulting data was systematic, as defined by the adjusted Johnson-Bickel criteria for systematic delay discounting data described below. The realized hourly wage for completion of the task (not including the bonus) was \$5. The HIT took an average of 24 minutes to complete. Systematic data were defined based on guidelines suggested by Johnson and Bickel in the money-money delay discounting condition (M. W. Johnson & Bickel, 2008). The guidelines stipulated that the individual's indifference points show a pattern of discounting such that the most delayed option (i.e., 1 year) was at least 10% less than the most proximal indifference point (i.e. the indifference point for a one day delay) and that the rate of discounting increased as a functioning of the delay such that the indifference point of each delay was equal to or less than the previous, with no more than one exception to the latter rule. These criteria have been used in previous in-person studies (e.g., Moody, Franck, & Bickel, 2016) as well as similar criteria employed in previous Mturk studies by this research group (e.g., Bickel, George Wilson, et al., 2014). The data from 38 participants were excluded from analysis on this basis.. Another six participants were excluded from analyses due to reports of never drinking alcoholic beverages leaving a total of 60 participants in the sample.

Questionnaires and Tasks

Delay Discounting Tasks—The delay discounting tasks each included five delays (i.e., 1 day, 1 week, 1 month, 6 months, 1 year) and followed a similar procedure to that originally used by Du et al. (2002). At each delay, the participant made six hypothetical choices between a titrating smaller, sooner amount of either money or alcohol and a static delayed \$1000 or the equivalent amount of alcohol depending on the assigned commodity in the task. The choice between a smaller, sooner and larger, later commodity were displayed at the same time on the computer screen and the participant clicked on the option they preferred. The delayed monetary amount or equivalent was \$1000 for all delay discounting tasks. The equivalent amount of alcohol was determined on an individual basis by having participants select a preferred type of alcohol (e.g., beer or a cocktail) and then having participants report the amount a single serving of the item typically cost (e.g., \$5). The reported cost for a single serving was then converted to the number of alcoholic drinks that could be purchased with \$1000 and the conversion was approved or edited by the participant to be accurate. For example, if the participant said that a cocktail typically cost \$5, then the participant was asked if they could buy 200 cocktails with \$1000. If the participant endorsed this as correct, the task proceeded forward. If the participant endorsed that this was not correct, the participant was instructed to revise the amount per drink until the amount per drink resulted in an amount of drinks the participant could buy with \$1000. Participants reported that an alcohol drink cost on average \$3.23 ($SD = 2.45$) making the average equivalent value between alcohol and money 309.60 drinks equivalent to \$1000.

Alcohol Use Disorders Identification Test (AUDIT)—The AUDIT is a 10-item self-report questionnaire developed by the World Health Organization to assess alcohol use, drinking behaviors, and problems related to alcohol use (Saunders, Aasland, Babor, de La Fuente, & Grant, 1993). AUDIT scores can range from 0 to 40 where 0 indicates no alcohol use. Clinical cutoffs for levels of use and recommendations for levels of interventions are provided where a score of less than 8 is a Zone 1 risk level and indicates low chance of alcohol misuse, scores between 8 and 15 are Zone 2 risk level and indicate that alcohol use exceeds low-risk and may warrant a brief intervention. Zone 3 risk level is composed of AUDIT scores between 16 and 19 and indicates harmful and hazardous drinking, finally Zone 4 risk level is a score between 20 and 40 and indicates a high probability of alcohol misuse and suggests the individual may need formalized treatment for an alcohol use disorder (Barbor, Higgins-Biddle, Saunders, & Monteiro, 2001).

Data Analysis

Following procedures proposed by Borges et al. (2016), the five delays in each of the delay discounting tasks were adjusted using ordinal transformation to eliminate pseudo-exponential scaling of the delay. The indifference points from each of the delay discounting tasks were then used to compute area under the delay discounting curve (AUC; Myerson, Green, & Warusawitharana, 2001). AUC was chosen because it does not make assumptions about the nature of the discounting curve that are implicit in other commonly used measures such as the hyperbolic discounting function. The AUC equation is

$$(x_2 - x_1)[(y_1 + y_2)/2] \quad (1)$$

where x_1 and x_2 are the ordinal representation of sequential delays and y_1 and y_2 are the subjective discounting values at each delay. Equation (1) produces the AUC by summing the areas of the trapezoids calculated across the delays. All AUCs are represented as a proportion of the maximum AUC possible for the given task, and range between 0.0 and 1.0, where smaller values represent more discounting. The AUCs were calculated in Prism 6.0 (Graphpad Software, 2015) and all subsequent analyses were conducted in R (R Core R Core Team, 2014).

First, a one-way within-participants analysis of variance (ANOVA) was conducted to compare the four delay discounting tasks across all participants, followed by Tukey's HSD pairwise comparisons of delay discounting tasks. Second, an effect of clinical Zone from the AUDIT (Zone 1 [$N=17$], Zone 2 [$N=21$], Zone 3 [$N=11$], and Zone 4 [$N=11$]) on delay discounting AUC from each of the delay discounting tasks was assessed using one-way between subjects ANOVAs to investigate possible differences in delay discounting tasks across AUDIT Zones. Significant omnibus effects were then examined using post hoc Tukey's HSD pairwise comparisons to assess differences between AUDIT Zones after adjusting for multiple comparisons. Hedges' g was used to report effect sizes of pairwise comparisons. Hedges' g includes a correction factor for small effect sizes and effect size conventions are small (0.2), medium (0.5), and large (0.8) (Cohen, 1988). As a secondary analysis, linear regressions of the AUDIT score as a continuous variable were used to predict the AUC of each of the delay discounting tasks. In addition, one-way within subjects ANOVAs, followed by Tukey's HSD pairwise comparisons, were used to assess for possible differences in AUC values between delay discounting tasks for light alcohol users (Zone 1 AUDIT scores) and in heavy alcohol users (Zone 4 AUDIT scores). Lastly, to test if the range of AUCs across delay discounting tasks decreases in Zone 4 participants compared to Zone 1 participants, an independent samples t-test of the difference in the overall highest and lowest task AUCs in Zone 4 compared to Zone 1 participants was performed.

Results

The sample ($N=60$) demographic variables are characterized in Table 1. The omnibus test of differences between delay discounting tasks was significant ($F_{(3,236)}=111.20$, $p<0.001$, $\eta^2=0.41$). Tukey's HSD pairwise comparisons indicate that all delay discounting tasks were significantly different from one another after accounting for familywise error. Alcohol now-money later ($M=0.76$, $SD=0.07$) and alcohol now-alcohol later ($M=0.49$, $SD=0.22$, $p<0.001$), money now-alcohol later ($M=0.19$, $SD=0.22$) and alcohol now-alcohol later ($p<0.001$), money now-money later ($M=0.59$, $SD=0.14$) and alcohol now-alcohol later ($p=0.012$), money now-alcohol later and alcohol now-money later ($p<0.001$), money now-money later and alcohol now-money later ($p<0.001$), and money now-money later and money now-alcohol later ($p<0.001$) were all significantly different from each other (see Figure 1).

In addition, delay discounting was significantly associated with AUDIT Zones for both of the cross-commodity conditions (alcohol now-money later $F_{(3,56)}=13.22$, $p<0.001$, $\eta^2=0.41$; money now-alcohol later: $F_{(3,56)}=2.78$, $p=0.04$, $\eta^2=0.13$). No significant effect was observed for either of the same-commodity conditions (alcohol now-alcohol later: $F_{(3,56)}=0.83$, $p=0.48$, $\eta^2=0.04$; money now-money later: $F_{(3,56)}=0.93$, $p=0.43$, $\eta^2=0.05$). See Figure 2 for graphic depiction of association between AUDIT Zone and delay discounting task. Both of the cross-commodity delay discounting tasks were further explored using Tukey's HSD comparisons to assess for differences between the AUDIT Zones while simultaneously accounting for multiple comparisons (see Table 2). In the alcohol now-money later delay discounting task, significant differences were found between Zone 4 ($M=0.66$, $SD=0.12$) and Zone 1 ($M=0.78$, $SD=0.03$) with $p<0.001$ (Hedges' $g=1.48$); Zone 2 ($M=0.78$, $SD=0.03$) with $p<0.001$ (Hedges' $g=1.60$); and Zone 3 ($M=0.78$, $SD=0.02$) with $p<0.001$ (Hedges' $g=1.33$). In the money now-alcohol later delay discounting condition, Zone 1 ($M=0.07$, $SD=0.08$) and Zone 2 ($M=0.25$, $SD=0.24$; $p=0.04$; Hedges' $g=-0.94$) were significantly different. The comparison in the money now-alcohol later delay discounting condition between Zone 1 and Zone 3 ($M=0.21$, $SD=0.22$; $p=0.16$; Hedges' $g=-0.89$) as well as Zone 1 and Zone 4 ($M=0.25$, $SD=0.27$; $p=0.06$; Hedges' $g=-0.99$) were not statistically significant. Yet, the Hedges' g effect sizes between Zone 1 and Zone 3 of -0.89 and between Zone 1 and Zone 4 of -0.99 were large based on the conventions of Cohen (1988), thus indicating that with larger sample sizes significant differences may have been detected. See Table 2 for all pairwise comparisons. Since large effects were observed in the alcohol now-money later delay discounting condition for all pairwise comparisons with Zone 4 and in the money now-alcohol later delay discounting condition for all pairwise comparisons with Zone 1, the AUCs for these two tasks are shown in Figure 3.

A secondary analysis using linear regression shows similar patterns between AUDIT score and the AUC from each delay discounting task. AUDIT score was significantly associated with the AUC of the delay discounting task for both of the cross-commodity conditions (alcohol now-money later: $F_{(1,58)}=29.30$, $p<0.001$, $R^2=0.34$; money now-alcohol later: $F_{(1,58)}=3.86$, $p=0.04$, $R^2=0.06$) while no significant relationship was observed in the same-commodity conditions (money now-money later: $F_{(1,58)}=0.67$, $p=0.41$, $R^2=0.01$, *ns*; alcohol now-alcohol later: $F_{(1,58)}=0.76$, $p=0.39$, $R^2=0.01$, *ns*). To determine differences in discounting rates between tasks for light alcohol users, the AUCs for each delay discounting task were compared for the Zone 1 (light) alcohol users. The omnibus effect of Zone 1 AUCs across discounting tasks was significant ($F_{(3,64)}=57.49$, $p<0.001$). Tukey's HSD pairwise comparisons were all significant (alcohol now-money later vs. alcohol now-alcohol later, $p=0.03$; money now-alcohol later vs. alcohol now-alcohol later, $p<0.001$; money now-alcohol later vs. alcohol now-money later, $p<0.001$; money now-money later vs. money now-alcohol later, $p<0.001$; money now-money later vs. alcohol now-money later, $p<0.01$) except money now-money later vs. alcohol now-alcohol later ($p=0.25$). Independently, the AUCs for the Zone 4 (heavy) alcohol users were also compared. The omnibus effect of Zone 4 AUCs across discounting tasks was also significant ($F_{(3,40)}=9.58$, $p<0.001$). Tukey's HSD comparisons were only significant in three of the pairwise comparisons (alcohol now-money later vs. alcohol now-alcohol later, $p=0.02$; money now-alcohol later vs. alcohol now-money later, $p<0.001$; money now-money later and money now-alcohol later, $p<0.01$). Comparison

of AUCs in light (Zone 1) and heavy (Zone 4) drinkers indicates greater differences between delay discounting condition choices in light drinkers than in heavy drinkers, with five of the pairwise comparisons between delay discounting task AUCs showing significant differences in light drinkers compared to only three of the discounting tasks in the heavy drinking conditions. See Figure 3 for visual depiction of differences in rates of discounting in Zone 1 and Zone 4. Independent samples t-test of the difference in AUCs for the two cross commodity tasks (i.e. alcohol now-money later and money later-alcohol now), which make up the highest and lowest rates of discounting in both Zone 1 ($M=0.71$) and Zone 4 ($M=0.41$) participants were compared and also indicated a significant effect ($t=2.86$, $p=0.01$) indicating a difference in the range of discounting between low and high drinkers.

Discussion

The goal of the present study was to examine patterns of decision-making across same- and cross-commodity delay discounting tasks in alcohol users. To this end, alcohol users were enrolled and completed four delay discounting tasks where choices between proximal or distal amounts of money and/or alcohol were presented. Participants showed orderly discounting across the tasks such that alcohol now, money later was discounted the least and money now, alcohol later was discounted the most regardless of alcohol use severity (see Figure 1). Alcohol was discounted more than money in the same-commodity tasks suggesting a steeper rate of discounting when the commodity is a substance of abuse as opposed to money and is consistent with the results of previous studies (M. W. Johnson et al., 2010, 2007; Weatherly et al., 2010). Also of possible interest, the current study did not detect a difference in discounting in the money now, money later condition between varying degrees of alcohol use. While a preponderance of research shows that substance use is associated with increased rates of monetary delay discounting, we note that 35% of studies comparing alcohol users to controls in a meta-analysis of alcohol use and delay discounting also did not detect differences between groups (MacKillop et al., 2011).

The results reported here also align with the previous observation of same- and cross-commodity delay discounting in cocaine users (Bickel et al., 2011). Both cocaine and alcohol users show devaluation of delayed commodities in cocaine (Bickel et al., 2011) or alcohol (this paper), in addition to comparatively more valuation when the delayed commodity is money. However, heavy alcohol users value alcohol more (regardless if alcohol is the proximal or distal option) in the cross-commodity conditions, a finding that is in contrast to observations in cocaine users (Bickel et al., 2011). One possible explanation for this difference is that heavy alcohol users may not be suffering from as severe of substance use and, as such, do not show as extreme of discounting of distal rewards. Indeed, this possibility is supported by previous work showing that the amount of delay discounting tracks with the severity of the addiction, at least in the case of pathological gambling (Alessi & Petry, 2003), and that cocaine users discount more than alcohol users with regard to same-commodity monetary tasks (Moody, Franck, Hatz, & Bickel, 2016).

Initial evidence suggests that delay discounting becomes more constricted as a function of substance use severity. This is to say that individuals with very severe substance use disorders may lack variability and flexibility in choice patterns and thus may be more likely

to make similar choices regardless of the commodities available. In unpublished work our team has found that recreational cocaine users had less variability in delay discounting across four conditions (i.e., cocaine now, cocaine later; cocaine now, money later; money now, money later; and money now, cocaine later) than healthy controls. In agreement with these findings, chronic cocaine users showed less variability in discounting than recreational cocaine users, indicating a systematic decrease in variability, or constriction of discounting rates, as cocaine use severity increased. Here, we provide a comparable look at the difference in discounting across conditions in light (Zone 1) and heavy (Zone 4) alcohol users. The four delay discounting tasks show a less dispersed pattern of discounting in heavy alcohol users than light users (Zone 1; see Figure 2). That is, the AUCs in Zone 4 users are more closely clustered together than in the Zone 1 alcohol users. In fact, the difference in the AUC for the delay discounting condition with the most delay discounting (i.e., money now-alcohol later) and with the least delay discounting (i.e., alcohol now-money later) is significantly different between Zone 1 (light) and Zone 4 (heavy) alcohol users, quantitatively confirming the visual construction evident in Figure 2.

In the cross-commodity tasks when alcohol is the distal commodity, the heaviest users (Zone 4) discount markedly less than all others. In contrast, when money is the distal commodity, the lightest alcohol users (Zone 1) discount less than all others (see Table 2 and Figure 3). These results indicate a profile of discounting that emerges when considering the cross-commodity choices wherein a symmetry in the extremities of alcohol users (Zone 1 and Zone 4) show opposite valuation patterns. In the cross-commodity conditions opposite decision making patterns can be observed between light and heavy drinkers. Light drinkers show excessive discounting of alcohol in the money now, alcohol later condition, above and beyond the discounting of more severe alcohol users. Conversely, heavy drinkers show increased discounting of money in the alcohol now, money later condition compared to less severe drinkers. This pattern of discounting observed in the cross-commodity discounting conditions may point to a variety of reinforcer pathology (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014) that is only evident in the most extreme ends of alcohol use.

The constriction of discounting values in the heavy alcohol users suggests less variable and less flexible choice patterns compared to light alcohol users that may be characteristic to more problematic drinking. Heavy alcohol users may constitute a unique subtype of alcohol drinkers that is characterized by excessive valuation of alcohol leading to disproportionate choices for alcohol regardless of its temporal location. Indeed, the two cross-commodity delay discounting tasks (i.e., alcohol now-money later and money now-alcohol later) were the only ones to show differences between light and heavy alcohol users. As such, these cross-commodity tasks may be more sensitive to differences in choice patterns than the same-commodity delay discounting tasks.

The cross-commodity tasks assess more real-world choice patterns which may be instrumental in characterizing and perhaps treating alcohol use disorders. Specifically, cognitive and behavioral treatment may benefit from an emphasis on the comparative value of commodities that are and are not drug related. For instance, a treatment provider might engage an alcohol user in discussions of the value of alcohol now as compared to alternative reinforcers in the future. Likewise, considerations between the value of small and perhaps

seemingly insignificant non-alcohol reinforcers now could be contrasted with the potential of continued alcohol consumption in the future. By probing into the value of different reinforcers across time, treatment providers may be able to point out inconsistencies and perhaps change how an individual makes choices as they relate to drug and alcohol use as compared to other commodities.

Some limitations of the study should be noted. The current delay discounting tasks used \$1000 or the equivalent amount of alcoholic beverage as the magnitude of all tasks. This large magnitude may have made some of decisions where the participant had to consider large quantities of alcoholic beverages difficult to make realistic choices about. Future work on this topic would benefit from laboratory studies with small magnitude discounting tasks, such as \$10 or \$100, that may make the choices easier to comprehend. In addition, 36% of the collected data was excluded due to nonsystematic delay discounting. This rate of exclusion is consistent with other published MTurk delay discounting studies (Herrmann, Johnson, & Johnson, 2015; P. S. Johnson, Herrmann, & Johnson, 2015).

In conclusion, the current study provides evidence of differential rates of cross-commodity delay discounting in light and heavy alcohol users. Heavy alcohol users, similarly to chronic cocaine users, have a constricted rate of discounting compared to light alcohol users that is particularly distinct in cross-commodity discounting conditions. These findings suggest that using cross-commodity discounting as an indicator of addiction severity and possible marker of successful treatment may prove useful in clinical settings. Furthermore, in heavy alcohol users, specific attention by health care providers regarding the excessive valuation of alcohol may provide a treatment target to facilitate changes in maladaptive decision-making.

Acknowledgments

This study was funded by NIAAA R01AA021529 and LNM's time was funded by NIAAA F31AA024368.

Grant funding for this manuscript was provided by the National Institute of Alcoholism and Alcohol Abuse (R01AA021529 and F31AA024368).

References

- Alessi SM, Petry NM. Pathological gambling severity is associated with impulsivity in a delay discounting procedure. *Behavioural Processes*. 2003; 64(3):345–354. [PubMed: 14580703]
- Barbor, TF., Higgins-Biddle, JC., Saunders, JB., Monteiro, MG. Alcohol Use Disorders Identification Test (AUDIT): Guidelines for use in primary care. 2. World Health Organization; 2001. Retrieved from http://www.talkingalcohol.com/files/pdfs/WHO_audit.pdf
- Bickel WK, George Wilson A, Franck CT, Terry Mueller E, Jarmolowicz DP, Koffarnus MN, Fede SJ. Using crowdsourcing to compare temporal, social temporal, and probability discounting among obese and non-obese individuals. *Appetite*. 2014; 75:82–89. [PubMed: 24380883]
- Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, Murphy JG. The behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annual Review of Clinical Psychology*. 2014; 10:641–677.
- Bickel WK, Landes RD, Christensen DR, Jackson L, Jones BA, Kurth-Nelson Z, Redish AD. Single- and cross-commodity discounting among cocaine addicts: the commodity and its temporal location determine discounting rate. *Psychopharmacology*. 2011; 217(2):177–187. [PubMed: 21487658]

- Borges AM, Kuang J, Milhorn H, Yi R. An alternative approach to calculating Area-Under-the-Curve (AUC) in delay discounting research. *Journal of the Experimental Analysis of Behavior*. 2016; 106(2):145–155. [PubMed: 27566660]
- Cohen J. *Statistical power analysis for the behavioral sciences* Lawrence Earlbaum Associates. Hillsdale, NJ. 1988:20–26.
- Du W, Green L, Myerson J. Cross-cultural comparisons of discounting delayed and probabilistic rewards. *The Psychological Record*. 2002; 52(4):479.
- Graphpad Software. Prism (Version 6.0f for Mac OS X). 2015. Retrieved from www.graphpad.com
- Herrmann ES, Johnson PS, Johnson MW. Examining Delay Discounting of Condom-Protected Sex Among Men Who Have Sex with Men Using Crowdsourcing Technology. *AIDS and Behavior*. 2015; 19(9):1655–1665. [PubMed: 26066395]
- Johnson MW, Bickel WK. An algorithm for identifying nonsystematic delay-discounting data. *Experimental and Clinical Psychopharmacology*. 2008; 16(3):264–274. [PubMed: 18540786]
- Johnson MW, Bickel WK, Baker F. Moderate drug use and delay discounting: a comparison of heavy, light, and never smokers. *Experimental and Clinical Psychopharmacology*. 2007; 15(2):187–194. [PubMed: 17469942]
- Johnson MW, Bickel WK, Baker F, Moore BA, Badger GJ, Budney AJ. Delay discounting in current and former marijuana-dependent individuals. *Experimental and Clinical Psychopharmacology*. 2010; 18(1):99–107. [PubMed: 20158299]
- Johnson NB, Hayes LD, Brown K, Hoo EC, Ethier KA, for Disease Control, C. et al. CDC National Health Report: leading causes of morbidity and mortality and associated behavioral risk and protective factors—United States, 2005–2013. *Morbidity and Mortality Weekly Report Surveillance Summaries*. 2014; 63(Suppl 4):3–27.
- Johnson PS, Herrmann ES, Johnson MW. Opportunity costs of reward delays and the discounting of hypothetical money and cigarettes. *Journal of the Experimental Analysis of Behavior*. 2015; 103(1):87–107. [PubMed: 25388973]
- Kirby KN, Petry NM, Bickel WK. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology General*. 1999; 128(1):78–87. [PubMed: 10100392]
- MacKillop J. *The Behavioral Economics and Neuroeconomics of Alcohol Use Disorders*. Alcoholism, Clinical and Experimental Research. 2016; 40(4):672–685.
- MacKillop J, Amlung MT, Few LR, Ray LA, Sweet LH, Munafò MR. Delayed reward discounting and addictive behavior: a meta-analysis. *Psychopharmacology*. 2011; 216(3):305–321. [PubMed: 21373791]
- McKerchar TL, Mazur JE. Human choices between variable and fixed rewards in hypothetical variable-delay and double-reward discounting procedures. *Journal of the Experimental Analysis of Behavior*. 2016; 106(1):1–21. [PubMed: 27353633]
- Mellis AM, Woodford AE, Stein JS, Bickel WK. A second type of magnitude effect: Reinforcer magnitude differentiates delay discounting between substance users and controls. *Journal of the Experimental Analysis of Behavior*. 2017; 107(1):151–160. [PubMed: 28101922]
- Meredith SE, Sweeney MM, Johnson PS, Johnson MW, Griffiths RR. Weekly Energy Drink Use Is Positively Associated with Delay Discounting and Risk Behavior in a Nationwide Sample of Young Adults. *Journal of Caffeine Research*. 2016; 6(1):10–19. [PubMed: 26989563]
- Mitchell SH. Effects of short-term nicotine deprivation on decision-making: delay, uncertainty and effort discounting. *Nicotine & Tobacco Research: Official Journal of the Society for Research on Nicotine and Tobacco*. 2004; 6(5):819–828. [PubMed: 15700917]
- Moody L, Franck C, Bickel WK. Comorbid depression, antisocial personality, and substance dependence: Relationship with delay discounting. *Drug and Alcohol Dependence*. 2016; 160:190–196. [PubMed: 26846198]
- Moody L, Franck C, Hatz L, Bickel WK. Impulsivity and Polysubstance Use: A Systematic Comparison of Delay Discounting in Mono-, Dual-, and Trisubstance Use. *Experimental and Clinical Psychopharmacology*. 2016; 24(1):30–37. [PubMed: 26691847]
- Myerson J, Green L, Warusawitharana M. Area under the curve as a measure of discounting. *Journal of the Experimental Analysis of Behavior*. 2001; 76(2):235–243. [PubMed: 11599641]

- Paolacci G, Chandler J. Inside the Turk: Understanding Mechanical Turk as a participant pool. *Current Directions in Psychological Science*. 2014; 23(3):184–188.
- Petry NM. Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. *Psychopharmacology*. 2001; 154(3):243–250. [PubMed: 11351931]
- R Core Team. R: A language and environment for statistical computing. Vol. 2013. R Foundation for Statistical Computing; Vienna, Austria: 2014.
- Reed DD, Becirevic A, Atchley P, Kaplan BA, Liese BS. Validation of a Novel Delay Discounting of Text Messaging Questionnaire. *The Psychological Record*. 2016; 66(2):253–261.
- Sacks JJ, Gonzales KR, Bouchery EE, Tomedi LE, Brewer RD. 2010 National and State Costs of Excessive Alcohol Consumption. *American Journal of Preventive Medicine*. 2015; 49(5):e73–9. [PubMed: 26477807]
- 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(6):791–804. [PubMed: 8329970]
- Stahre M, Roeber J, Kanny D, Brewer RD, Zhang X. Contribution of excessive alcohol consumption to deaths and years of potential life lost in the United States. *Preventing Chronic Disease*. 2014; 11:E109. [PubMed: 24967831]
- Weatherly JN, Terrell HK, Derenne A. Delay discounting of different commodities. *The Journal of General Psychology*. 2010; 137(3):273–286. [PubMed: 20718227]
- Wesley MJ, Lohrenz T, Koffarnus MN, McClure SM, De La Garza R 2nd, Salas R, Montague PR. Choosing Money over Drugs: The Neural Underpinnings of Difficult Choice in Chronic Cocaine Users. *Journal of Addiction*. 2014; 2014:189853. [PubMed: 25197609]
- Yoon JH, Higgins ST, Bradstreet MP, Badger GJ, Thomas CS. Changes in the relative reinforcing effects of cigarette smoking as a function of initial abstinence. *Psychopharmacology*. 2009; 205(2): 305–318. [PubMed: 19390842]

Figure 1.

Mean AUC + SEM. Figure depicts mean AUC of all participants ($N=60$) for each delay discounting task. * indicates significant Tukey's HSD pairwise comparison at $p < 0.05$ level. A-M is alcohol now-money later delay discounting task, M-M is money now-money later delay discounting task, A-A is alcohol now-alcohol later delay discounting task, and M-A is money now-alcohol later delay discounting task. Note: AUCs were calculated using ordinaly transformed delays.

Figure 2.

Mean AUC $\pm$ SEM of all delay discounting tasks by AUDIT Zone. A-M is alcohol now-money later; M-M is money now-money later, A-A is alcohol now-alcohol later, and M-A is money now-alcohol later delay discounting task. Note: AUCs were calculated using ordinal transformed delays.

Figure 3.

Mean AUC $\pm$ SEM of cross-commodity delay discounting tasks by AUDIT Zone of symptom severity. * indicates statistically significant Tukey's HSD pairwise comparisons at $p < 0.05$ level. Note: AUCs were calculated using ordinal transformed delays.

Table 1

Demographic characteristics of the sample.

Demographics		
	n	%
Gender		
Female	31	51.7
Race		
White	54	90.0
Black	1	1.7
American Indian	1	1.7
Alaska Native	0	0.0
Asian	2	3.3
Pacific Islander	0	0.0
Other	2	3.3
Education		
High school	5	8.3
Some college	31	51.7
Bachelor's degree	22	36.7
Advanced degree	2	3.3
Employment		
Working full or part time	50	83.3
Not currently working	10	16.7
Ethnicity		
Hispanic	6	10.0
Marital status		
Single (never married)	23	38.3
Married or cohabitating	34	56.7
Divorced	3	5.0
Income		
<20k	9	15
20k-50k	29	48.3
>50k	20	33.3
Prefer not to say	2	3.3
Age ^a	33.07(9.49)	

Table 1: Demographics of sample are reported.

^a = variable that is reported with mean and standard deviation.

Table 2
Tukey's HSD pairwise comparisons of delay discounting AUC by AUDIT Zones

	Mean Diff	adjusted p-value	Hedges' g	95% Confidence Interval	
				Lower Bound	Upper Bound
Alcohol now-money later comparisons					
Zone 1 vs. Zone 2	0.001	0.999	0.03	-0.051	0.049
Zone 1 vs. Zone 3	0.001	0.999	0.02	-0.060	0.059
Zone 1 vs. Zone 4	0.122	<0.001 [*]	1.48	-0.182	-0.062
Zone 2 vs. Zone 3	<0.001	0.999	0.01	-0.057	0.057
Zone 2 vs. Zone 4	0.121	<0.001 [*]	1.60	-0.179	-0.064
Zone 3 vs. Zone 4	0.121	<0.001 [*]	1.33	-0.187	-0.056
Money now-alcohol later comparisons					
Zone 1 vs. Zone 2	-1.412	0.046 [*]	-0.94	0.015	2.806
Zone 1 vs. Zone 3	-1.350	0.148	-0.88	-0.307	3.00
Zone 1 vs. Zone 4	-1.532	0.079 [†]	-0.99	-0.123	3.188
Zone 2 vs. Zone 3	0.063	0.999	0.18	-1.655	1.529
Zone 2 vs. Zone 4	-0.122	0.997	0.01	-1.470	1.714
Zone 3 vs. Zone 4	-0.184	0.983	-0.17	-1.639	2.008

* indicates significant at p<0.05 level,

[†] indicates p<0.10.