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Valuation of Future Alcohol in Cross-Commodity Delay Discounting Is Associated With Alcohol Misuse/Consequences

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Abstract

Objective: Delay discounting (DD) refers to the reduction in reward value as a function of its delay, and individuals who misuse alcohol typically exhibit high rates of DD, which may reflect a general preference for immediate outcomes. This interpretation is based on studies utilizing single-commodity DD tasks where the same commodity is available immediately and following a delay. Cross-commodity DD tasks require individuals to choose between different commodities at varying delays and may provide the potential to further illuminate intertemporal preference associated with alcohol misuse. The present study examined associations between single-commodity and cross-commodity DD rates with alcohol use metrics among young adults.

Method: DD by young adults (N = 70, aged 19–24, 71% male, 80% White) who engage in hazardous drinking was examined using a fully parametric combination of immediate and delayed alcohol and money outcomes. We hypothesized that past 30-day alcohol use and alcohol-related negative consequences would be associated with preference for alcohol outcomes independent of whether alcohol was immediate or delayed.

Results: Results support the hypothesis, as past 30-day consumption and AUDIT scores were positively associated with rate of DD in the immediate alcohol versus delayed money task and negatively associated with rate of DD in the immediate money versus delayed alcohol task. Moreover, we found the immediate money versus delayed alcohol task provided unique explanatory power for individual alcohol use.

Conclusions: The observed associations indicate that willingness to invest in future access to alcohol may be associated with elevated alcohol use and related consequences.

Keywords

delay discounting; intertemporal choice; preference; alcohol use; young adults

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Hailey Taylor played lead role in data curation, project administration, validation, visualization and writing of original draft, supporting role in conceptualization, investigation and writing of review and editing and equal role in formal analysis. Aaron P. Smith played supporting role in conceptualization and supervision and equal role in formal analysis, methodology and writing of review and editing. Richard Yi played lead role in conceptualization, funding acquisition, resources, supervision and writing of review and editing and equal role in methodology.

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Howard Rachlin was an early adopter of the application of economic concepts to the study of individual behavior (e.g., Rachlin, 1992; Rachlin et al., 1980). Both his early efforts to align the existing body of animal research with the model of human choice from Daniel Kahneman and Amos Tversky (Rachlin et al., 1986) that is now considered the inception of behavioral economics (Laibson & Zeckhauser, 1998), as well as his subsequent conceptions within the field of behavioral economics (Rachlin, 1995) highlight the importance of behavioral science in understanding the behavior of individuals and groups. Rightly acknowledged as one of the founders of behavioral economics (Killeen et al., 2021), Rachlin has greatly influenced the body of work applying the concept of delay discounting to the study of addiction.

Delay discounting (DD) refers to a decrease in the subjective value of an outcome due to its delay (Odum, 2011). High rates of DD are indicative of a preference for immediate rewards, and behavioral economic models of addiction implicate DD as a principal feature of addiction (see Becker & Murphy, 1988; review in Rachlin, 1997). Rooted in early studies showing that animal behavior is systematically impacted as a function of the delay interval to reinforcement (e.g., Baum & Rachlin, 1969; see also Chung, 1965; Logan, 1965), subsequent studies of delay discounting in humans generally link high rates of DD with misuse of alcohol and other substances (Amlung et al., 2017; Petry, 2001; MacKillop et al., 2011; Vuchinich & Simpson, 1998) using binary-choice, single-commodity tasks where participants indicate a preference between different sums of money available immediately and following a delay (i.e., immediate money vs. delayed money). Though this association has not been universally observed in the study of alcohol use (e.g., Dennhardt & Murphy, 2011; MacKillop et al., 2007; Stojek et al., 2014) particularly for continuous variables of alcohol use (Amlung et al., 2017), Acuff et al. (2018) have offered reasonable explanations that do not dispute the relevance of the DD construct to the study of substance misuse (see Bailey et al., 2021, for dissenting perspective).

With the recognition that other nonmonetary commodities have different consumption characteristics (Rachlin, 1992), Rachlin has been particularly instrumental in innovating these procedures to consider the valuation of nonmonetary commodities (e.g., Raineri & Rachlin, 1993). Given the valuation of drug outcomes to individual who engage in drug use/misuse, DD tasks have been modified to examine the delayed value of the preferred drug of use (e.g., immediate drug vs. delayed drug). When compared to rates of DD from tasks with monetary outcomes, this research has consistently found that individuals who engage in drug misuse exhibit higher rates of DD in single-commodity tasks with drug outcomes (review in Odum et al., 2020). In particular, individuals who engage in alcohol misuse exhibit steeper rates of DD for alcohol than money in single-commodity DD tasks (Lemley et al., 2016; Petry, 2001; Yankelevitz et al., 2012).

These results have been interpreted as evidence that individuals who engage in substance misuse exhibit a generalized inability or unwillingness to wait for delayed rewards, which are particularly exacerbated for a preferred drug reward (Odum et al., 2020). This interpretation is consistent with behavior typically observed in individuals who engage in drug misuse, as key characteristics of addiction, including overvaluation of drug rewards

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and undervaluation of future rewards, appear to be analogous with preference for immediate outcomes exhibited in high rates of DD (Bickel, Jarmolowicz, et al., 2011, Bickel et al., 2014; MacKillop, 2016).

However, Pritschmann et al. (2021) argue that this interpretation that individuals who engage in substance misuse have a reduced ability to wait for the drug of choice, which is primarily informed from review of studies implementing single-commodity DD tasks, could be incomplete (see also Green & Myerson, 2019). Specifically, findings from the few studies using cross-commodity DD tasks, in which participants indicate a preference between an immediate commodity (e.g., money or alcohol) and a different delayed commodity, provide some evidence that does not align with such an interpretation.

For example, in an online sample of alcohol users, Moody et al. (2017) implemented single-commodity DD tasks with money and alcohol outcomes (i.e., immediate money vs. delayed money [money/money] and immediate alcohol vs. delayed alcohol [alcohol/alcohol]) and cross-commodity DD tasks (immediate alcohol vs. delayed money [alcohol/money] and immediate money vs. delayed alcohol [money/alcohol]). Rank ordering of the rates of DD from these four tasks, from lowest to highest was as follows: alcohol/money, money/money, alcohol/alcohol, and money/alcohol. Of note is that the lowest rates of DD (indicating preference for the delayed outcome) were observed in tasks with delayed money, while the highest rate of DD (indicating preference for the immediate outcome) was observed in the task with immediate money. Additionally, rate of DD in the money/alcohol task was significantly higher than that in the alcohol/money task. A fair interpretation of this pattern of results is that money was preferred relative to a comparably valued amount of alcohol, regardless of whether the money was immediate or delayed (e.g., participants exhibited a *willingness to wait* for delayed money despite the availability of immediate alcohol). Naude et al. (2021), in an online sample of participants who endorse recent alcohol and cannabis use, also included a fully parametric combination of money and alcohol outcomes in single- and cross-commodity DD tasks (as well as cannabis outcomes), and similarly observed lowest rates of DD in tasks with delayed money, the highest rates of DD in the task with immediate money, and significantly higher rate of DD in the money/alcohol task compared to the alcohol/money task.

Other studies using single-commodity DD and cross-commodity DD tasks (Bickel, Landes, et al., 2011; Wesley et al., 2014; see also Pericot-Valverde et al., 2020) have observed similar patterns among individuals who engage in substance misuse (e.g., cocaine). While the rank ordering from Moody et al. (2017) and Naude et al. (2021) have not been exactly replicated across all studies in comparable single- and cross-commodity DD tasks, what has been observed is a common pattern with the highest rate of DD in the money/drug task (indicating a preference for immediate money) and relatively low rates of DD in tasks where money is delayed (indicating a preference for delayed money), particularly in the drug/money task. Again, this pattern of results suggests individuals who engage in drug misuse (a) generally prefer monetary rewards to drug rewards and (b) specifically prefer delayed money even when the alternative is the immediate availability of a drug of choice. This differs from an interpretation that individuals who engage in alcohol misuse have a

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generalized unwillingness to wait for delayed outcomes that is particularly pronounced when presented with immediate access to alcohol.

The emerging interpretation is that individuals who engage in drug misuse can continue to value nondrug commodities (e.g., money) and may prefer delayed alternatives even when the drug may be immediately available. This interpretation of the valuation of drug outcomes relative to alternatives like money, combined with suggestive evidence that DD rates from cross-commodity DD tasks but not single-commodity DD tasks may be associated with problematic alcohol use, inform the rationale for the current project. Specifically, Moody et al. (2017) observed associations between ordinalized risk level derived from scores on the alcohol use disorders identification test (AUDIT) and area-under-the-curve measures (i.e., rate of DD) from cross-commodity tasks but not single-commodity tasks. Similarly, Naude et al. (2021) observed significant bivariate correlations between AUDIT and rate of DD from cross-commodity tasks but not single-commodity tasks. Of note, both sets of findings indicate *lower* rates of DD in the money/alcohol DD task as a function of higher AUDIT scores. The possibility that more hazardous drinking is associated with preference for delayed alcohol in lieu of immediate money has important implications for how problematic alcohol use can be conceptualized as well as strategies for intervention. Therefore, the current project seeks to extend the suggestive evidence of Moody et al. (2017) and Naude et al. (2021) by examining associations between alcohol use measures and patterns of single-commodity and cross-commodity DD in a sample of young adults who engage in hazardous drinking. For the purposes of this study, hazardous drinking was defined as engagement in binge drinking or heavy alcohol use in the last month, as defined by the National Institute on Alcohol Abuse and Alcoholism (NIAAA).

The objectives of the present study were (a) to replicate findings on rank order of DD rate across single- and cross-commodity conditions in a sample of college students who engage in hazardous drinking and (b) to explore associations between rates of DD in single-/cross-commodity tasks and alcohol use/misuse measures. We hypothesized to (a) generally replicate rank ordering of DD rates across single-commodity and cross-commodity DD tasks observed in previous research and (b) identify associations between cross-commodity DD rates with measures of alcohol use/misuse (informed by Pritschmann et al., 2021) such that individuals with greater alcohol use and related consequences will show a relative preference for *alcohol* outcomes in cross-commodity DD tasks, that is, positive and negative associations with rates of DD in the alcohol/money and money/alcohol tasks, respectively. In other words, we expected that individuals with high alcohol use/consequences would have high DD rates in alcohol/money tasks (showing a preference for immediate alcohol) and low DD rates in money/alcohol tasks (showing a preference for delayed alcohol). Further, we explored which DD task(s) provided the most explanatory power for associations with alcohol use measures.

Method

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow journal article reporting standards (JARS; Appelbaum

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et al., 2018). All data cleaning and analysis were computed using SPSS (Version 26). This study's design and its analysis were not pre-registered. Materials and analysis code for this study are available by emailing the corresponding author. The study was approved by the University of Kansas institutional review board.

Participants

Eighty-one participants were recruited via posted flyers. Nine participants were excluded for not meeting inclusion criteria or failing to complete study measures, resulting in 72 total participants (sample size for the present study was informed by Moody et al., 2017, $N = 60$). Eligible participants were undergraduate students, aged 18–25 (i.e., young adults), who reported hazardous drinking in the past month by either (a) endorsing at least one episode of binge drinking *or* (b) engaging in heavy alcohol use, that is, drinking above the recommended weekly drinking limits as defined by the NIAAA (4/5 or more standard drinks in about 2 hr for females/males, and weekly drinking limits as an average of 7/14 or more drinks per week for females/males (National Institute on Alcohol Abuse and Alcoholism, 2020).

Measures

Delay Discounting Task—Delay discounting was assessed using the *5-trial Adjusting DD Task* (Koffarnus & Bickel, 2014). This task presented participants with five trials of a hypothetical, binary choice between a smaller-sooner (SS) reward and a larger-later (LL) reward (with 32 potential delays, 1 hr—25 years). For instance, in the first trial of the task with an LL reward of $200, participants chose between receiving half of the LL immediately (i.e., SS = $100) or the full LL ($200) in 3 weeks. Dependent on the selected choice, the next item increased or decreased the delay as defined by Koffarnus and Bickel (2014). The fifth and final trial determined the effective delay 50% (ED_{50}), representing the delay at which the delayed and immediate rewards were equally valued. As a titrating procedure, this task does not allow for inconsistent responding and the ED_{50} can be estimated any time the task is completed. As such, all participants had successful ED_{50} quantification. This DD task has been successfully used in other DD studies (Phung et al., 2019; Stein et al., 2017; Strickland et al., 2021).

Participants in the present study completed two single-commodity DD tasks (money/money, alcohol/alcohol) and two cross-commodity DD tasks (money/alcohol, alcohol/money). Each of the four tasks was completed for two magnitudes of the LL ($50, $200) or the alcohol equivalents—resulting in eight parametric combinations of DD tasks (see Table 1). Alcohol equivalences to monetary LL amounts were participant-dependent and determined using a procedure previously used by Stanger et al. (2012) in which participants indicated the number of standard drinks that would be equally attractive to the money amounts. Participants were asked to provide alcohol equivalences in the blank spaces provided following this statement:

> Imagine that you have a choice between receiving some money and receiving some alcohol. For the following statement, please fill in the number of standard drinks (beer—12 oz, wine—5 oz, shots of hard liquor—1.5 oz, or mixed drinks with one

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shot of liquor) that would make the two choices equally attractive to you. Receiving $50/$200 right now would be just as attractive as receiving ——/—— standard drinks.

Participants were instructed to indicate their preferred outcomes on the DD tasks as if they were real.

Alcohol Use Measures—The *alcohol use disorders identification test* (AUDIT; Saunders et al., 1993) is a widely utilized 10-item validated tool (Babor et al., 2001) used to identify individuals at risk for developing alcohol problems. Participants responded to questions regarding alcohol intake and AUD symptoms using a 5-point scale (from 0 to 4); questions about alcohol-related harm used a 3-point scale (0, 2, and 4)—scores on the AUDIT range from 0 to 40, with higher scores indicating greater individual risk.

The *timeline follow-back* (TLFB, Brown et al., 1998; Sobell & Sobell, 1992) methodology was adopted to assess the number of consumed standard alcoholic drinks during the past 30 days. Participants were given handouts with standard drink visuals and TLFB calendars were created and marked with relevant holidays and events to best assist participants with recall. The number of standard alcoholic drinks consumed in the past 30 days was summed to represent participant's alcohol consumption.

Procedure

During initial contact, the research assistant provided a brief study description and inclusion criteria. Individuals who self-identified as eligible to participate were scheduled for an in-person session. Following informed consent, participants completed a computerized survey that formally assessed inclusion criteria along with relevant demographic information. Participants who were deemed ineligible for the study immediately discontinued their session and were compensated $5 via prepaid ClinCards. Eligible participants completed all relevant study tasks, including the DD tasks, the AUDIT, and the TLFB. All tasks were computerized except for the TLFB, which was done on paper. Participants were compensated $10 after completion of study procedures. Due to a typographical error in some items of DSM-5 Alcohol Use Disorder Criteria (AUD) questionnaire, we were unable to confirm score accuracy and the AUD symptom count was excluded from analyses. Additional study procedures not relevant to this study are not reported here.

Data Analysis

All data from two participants were excluded for being outliers on multiple measures (values occurring greater than 3 *SDs* from the mean; Parke, 2013). Values from one $200 DD condition were excluded for two additional participants because they were outliers. This resulted in a final sample size of 70.

Rates of DD (k) were determined from the ED_{50} values measured in the DD tasks, as ED_{50} is the inverse of k (Yoon & Higgins, 2008). Rates of DD were then log-transformed ($\ln k$) to normalize distributions and allow for parametric analyses for all eight DD tasks (see Table 1). Bivariate correlations determined associations between all study constructs and assessed multicollinearity. A one-way analysis of variance (ANOVA) was conducted for

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each magnitude ($50 and $200) to compare the four DD tasks, followed by Tukey's honest significant difference (HSD) pair-wise comparisons.

Alcohol use variables (AUDIT and alcohol consumption) were transformed using natural logarithm to address nonnormality, with a value of 1 added to avoid transformed values of 0. To examine the predictive utility of DD tasks, AUDIT scores and past 30-day alcohol consumption were analyzed in two ways utilizing multiple linear regression. Following bivariate correlations, an omnibus method including all four DD tasks was used in a single multiple regression model, as has been previously done (Lemley et al., 2016). Second, to identify the incremental predictive power of each DD task, each parametric combination of the DD tasks alone and in combination were compared using Akaike information criterion (AIC; Burnham et al., 2011). When comparing between models, lower AIC values are preferred as this indicates models that have greater predictive accuracy. For one model to be meaningfully preferred relative to another, a threshold of absolute AIC differences (ΔAIC) of 2 or greater was selected as this indicates the preferred model is 2.4× more likely to be the correct model relative to the alternative (a ΔAIC of 4 indicates 7.4× likelihood). In cases where ΔAICs are subthreshold, the more parsimonious model (i.e., fewer estimated parameters) is preferred. The purpose of the model comparisons was to (a) compare the utility of cross-commodity DD as a class to single-commodity DD in predicting alcohol use and (b) determine whether all four DD tasks are necessary to achieve maximal predictive accuracy.

Results

Participant Characteristics

Participants included in analyses were 71.4% male, and 80% self-identified as White, with a mean age of 20.63 years (SD = 1.43). Participants self-reported drinking (via TLFB) an average of 33.92 drinks total in the past 30-days (SD = 23.64), with a mean of 7.69 drinks on a single occasion (SD = 3.03). The average participant AUDIT score was 10.21 (SD = 4.94); 68.6% of AUDIT scores were within the hazardous or harmful range for individual risk of developing alcohol-related difficulties (scores of 8 or more). All relevant participant characteristics are represented in Table 2.

For alcohol equivalences, participants included in analyses indicated that, on average, $50 was equally attractive to 27.73 standard drinks (SD = 24.07; range = 3–120) and $200 was equally attractive to 111.81 standard drinks (SD = 103.78; range = 7–500).

Analysis of Variance

The omnibus ANOVA comparing rates of DD across single-commodity and cross-commodity DD tasks for the $50 magnitude was significant, $F(3,276) = 43.79$, $p < .001$, see Figure 1). Tukey's HSD pair-wise comparisons indicate that nearly all DD tasks resulted in different DD rates, with most pairs being significantly different (all p's ≤ .001). The only exception was between MM50 and AM50 ($p = .995$).

The similar omnibus ANOVA for the $200 magnitude was also significant $F(3,268) = 104.41$, $p < .001$ (see Figure 1). Tukey's HSD pair-wise comparisons indicate that most DD

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tasks were significantly different (all *p*s < .001). The only exception was between MM200 and AM200 (*p* = .771).

Bivariate Correlations

The correlation matrix (Table 3) shows a pattern of strong positive correlations across magnitudes in the DD tasks. One noteworthy pattern is that associations between rate of DD in MA50 and both alcohol use measures were negative and met conventional levels of statistical significance (i.e., *p* < .05). The associations between rate of DD in MA200 and both alcohol use measures were also negative, though these associations were not significant.

Multiple Regressions

When controlling for all other DD tasks in the omnibus $50 magnitude models, MA50 was the only significant predictor of AUDIT scores (β = −0.042, *p* = .015) and past 30-day alcohol consumption (β = −0.048, *p* = .042). When controlling for all other DD tasks in the $200 magnitude models, no tasks were significant predictors of AUDIT or past 30-day alcohol consumption (all *p*s > .05; see Table 4).

Model Comparisons

A summary of model comparisons for all DD tasks is presented in Tables 5 and 6, separated by magnitude. In the $50 magnitude, AM50 was the single-model predictor with the best AIC score for AUDIT, though not sufficiently different from the MA50 model (ΔAIC = −0.13), and MA50 was the single-model predictor with the best AIC score for alcohol consumption, though also not sufficiently different from the AM50 model (ΔAIC = −0.38). When comparing the average AIC value for single-commodity DD models to cross-commodity DD models, cross-commodity DD models consistently do better as a class of DD measure for predicting AUDIT scores (ΔAIC = −3.885) and alcohol consumption (ΔAIC = −5.035; see Table 5). In the $200 magnitude single-predictor models, AM200 has the best AIC score for AUDIT and alcohol consumption. When comparing the average AIC value for single-commodity DD models to cross-commodity DD models, cross-commodity DD models consistently do better as a class for predicting AUDIT score (ΔAIC = −2.940) and alcohol consumption (ΔAIC = −3.300; see Table 6).

For multiple-predictor model comparisons in the $50 magnitude, the best AIC scores for double and triple-predictor models were models 10 (AM50 and MA50) and 13 (MM50, AM50, and MA50). Across classes in the $50 magnitude, single-predictor models are best for AUDIT and alcohol consumption. For both alcohol use measures in the $200 magnitude, the best AIC scores for double and triple-predictor were models 6 (MM200 and AM200) and 11 (MM200, AA200, and AM200). Across classes in the $200 magnitude, single-predictor models also do best for the AUDIT and alcohol consumption.

Discussion

The association between high rates of alcohol use/misuse and high rates of delay discounting in single-commodity tasks is well-established (Lemley et al., 2016; MacKillop et al., 2011;

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Odum et al., 2020; Petry, 2001; Vuchinich & Simpson, 1998; Yankelevitz et al., 2012). The resulting interpretation has been that individuals with high alcohol use/misuse rates exhibit a generalized *inability or unwillingness* to wait for delayed rewards. However, cross-commodity DD tasks present an opportunity to examine the interaction of alcohol rewards and delay to further enhance our understanding of alcohol use/misuse (Green & Myerson, 2019; Pritschmann et al., 2021). The present study expanded on recent work by examining the associations between single- and cross-commodity DD tasks and measures of alcohol use/consequences among young adults who engage in hazardous drinking. To our knowledge, no other research has examined the associations between rates of DD on cross-commodity tasks and measures of alcohol use/consequences in this population.

Our findings are consistent with recent studies in the general rank order of DD tasks (Bickel, Landes, et al., 2011; Moody et al., 2017; Naude et al., 2021; Wesley et al., 2014). The rank order of the four DD task's mean group rates, from lowest to highest, was the same for each magnitude ($50 and $200): alcohol/money, money/money, alcohol/alcohol, and money/alcohol. This rank ordering replicates Moody et al. (2017), with low DD rates in the alcohol/money task compared to high DD rates in the money/alcohol task. The general preference for money outcomes, regardless of temporal location found in the rank order of DD tasks, suggests that individuals who engage in alcohol misuse generally prefer immediate money to delayed alcohol *and* delayed money to immediate alcohol. This finding may indicate a willingness to wait for a delayed nonalcohol commodity (i.e., money) even if the immediate outcome is alcohol and this finding is consistent with the limited cross-commodity DD literature, as discussed previously (Bickel, Landes, et al., 2011; Moody et al., 2017; Naude et al., 2021; Wesley et al., 2014).

The replication of the rank order of DD tasks from Moody et al. (2017) and Naude et al. (2021) also gives us further confidence in the validity of the rest of this study's findings. Preliminary associations between DD tasks and alcohol use measures found in the bivariate correlations suggest the potential for cross-commodity DD tasks to be promising predictors of alcohol use/misuse measures. Our regression analyses confirmed these associations, specifically that cross-commodity DD tasks in the $50 magnitude were significant predictors of alcohol use measures, with the MA50 DD task exhibiting the strongest predictive accuracy for both 30-day alcohol consumption and AUDIT scores compared to other DD tasks. That the MA50 DD rate showed negative associations with these alcohol use measures (as did Naude et al., 2021 showed with AUDIT using bivariate correlations) suggests those individuals who consume more alcohol and are at higher risk for developing alcohol-related problems prefer *delayed* alcohol to immediate money more so than those with lower consumption or risk. From a behavioral economic perspective, this could be interpreted as indicating that individuals who engage in high rates of hazardous drinking are more willing to *invest* in future access to alcohol rewards despite the availability of immediate money. The money/alcohol DD task results partially contradict previous DD interpretations that suggest high rates of hazardous drinking are associated with a generalized inability or unwillingness to wait for delayed outcomes particularly in the face of immediate access to alcohol.

Of note, young adults in the present study who engage in the highest levels of alcohol misuse increasingly chose delayed alcohol to immediate money in the MA50 DD task,

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despite the difference in economic liquidity of alcohol versus money. That is, money has the characteristic of economic liquidity because it is exchangeable for many other rewards (including alcohol), whereas alcohol does not conventionally have this characteristic (Estle et al., 2007; Stuppy-Sullivan et al., 2016). This distinct pattern of choice in the MA50 DD task perhaps demonstrates a narrowed range of possible delayed reinforcers for individuals who engage in heavy alcohol misuse, such that even the availability of a liquid commodity such as money is relatively less valued than delayed access to alcohol. This appears to model the overvaluation of alcohol common to individuals who misuse alcohol due to a lack of alternative nonalcohol rewards in their environment—a hallmark of addiction (Bickel, Jarmolowicz, et al., 2011, Bickel et al., 2014; MacKillop, 2016).

Finally, the model comparison findings further corroborate the importance of cross-commodity DD tasks in predicting alcohol use/misuse measures. Naude et al. (2021) provided suggestive evidence of this, reporting that multivariate between-group analyses (with AUDIT scores dichotomized as harmful/nonharmful alcohol use) indicated significant differences in cross-commodity DD conditions but not single-commodity conditions. We extend these findings with explicit confirmation that cross-commodity DD tasks *as a class* provide more explanatory power than single-commodity DD among the single-predictor models, as the AIC values were sufficiently lower among the cross-commodity DD tasks for both alcohol use measures. Among the multiple-predictor models in the $50 magnitude, the preferred models within each model class (single, double, etc.) and the overall most predictive models for AUDIT scores and alcohol consumption included cross-commodity DD tasks. Moreover, we provide evidence that the money/alcohol DD task *in particular* provides unique explanatory power that is not accounted for by the single-commodity DD tasks nor the alcohol/money task. Overall, results from the $50 magnitude suggest implementing cross-commodity DD tasks may provide better accuracy in predicting alcohol use measures.

Findings from the $200 magnitude tasks were less conclusive. Although the results shared a similar pattern with the $50 magnitude tasks (i.e., cross-commodity DD tasks were present in the best interclass and overall preferred models), adding more DD tasks as predictors into the models tended not to improve AIC measures as much as the $50 magnitude tasks. We do not know why the pattern of results differed in these ways between the two DD magnitude conditions, though we speculate that purchasing/consumption decision for $50 worth of alcohol may represent meaningful and likely decisions for our sample of college drinkers, whereas $200 worth of alcohol may be outside of the range typically confronted by this group. As the findings from Naude et al. (2021) were observed for $10 magnitude outcomes (i.e., more comparable to our $50 magnitude outcome condition), the absence of clear associations between alcohol use/outcomes and DD for higher magnitude outcomes may indicate a limiting factor for when cross-commodity DD tasks provide most utility. Noting that the similarity of the present findings for $50 magnitude outcomes with those observed in Moody et al. (2017) and Naude et al. (2021), the overall pattern remains compelling that cross-commodity DD rates may be particularly useful predictors of alcohol use/consequences.

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Portions of our findings are inconsistent with some of the existing literature on this topic. For example, rate of DD in the money/money task was not associated with measures of alcohol use/consequences, despite established associations in previous research (reviews in MacKillop et al., 2011; Yi et al., 2010). However, the absence of associations between delay discounting in money/money tasks and measures of alcohol use is not unprecedented (e.g., Dennhardt & Murphy, 2011; MacKillop et al., 2007; Stojek et al., 2014), particularly for continuous measure of alcohol use (Amlung et al., 2017) among young adult samples (Acuff et al., 2018). One likely explanation is the present study's sample, which was largely homogenous in engaging in hazardous drinking. Much of the extant literature has assessed a sample of individuals with a larger range of alcohol use (Petry, 2001; Vuchinich & Simpson, 1998), and this narrowed sample range may have also affected the relatively small range of improvements in AIC values across model comparisons within each magnitude. Consistent with this interpretation, our results in the single-commodity tasks also align with those observed in Moody et al. (2017) and Naude et al. (2021).

Limitations

There are some limitations to note from the present study. Foremost, the in-person data collection for this project was interrupted by the COVID-19 pandemic. Given likely changes in drinking patterns among our target sample of college students during and resulting from the COVID pandemic, as well as potential changes in how individuals value future outcomes, we determined that simple transition of the project to fully online data collection methods or reactivation of in-person data collection following recent institutional approval of in-person activities could not be justified. This resulted in a smaller sample size than initially planned, and it is possible that the lack of systematic results observed in the $200 magnitude DD conditions are due to diminished statistical power. We note here that our sample size surpasses the $n = 60$ of Moody et al. (2017), and that the results obtained in the $50 magnitude conditions are consistent with those observed in all previous published studies of cross-commodity DD (Bickel, Landes, et al., 2011; Moody et al., 2017; Naude et al., 2021; Pericot-Valverde et al., 2020; Wesley et al., 2014). Nonetheless, future work should verify the reliability of the results reported here. A second limitation is that the DD tasks in the present study used hypothetical money and alcohol outcomes. Though the extant DD literature has established that rates of DD from tasks that using hypothetical money outcomes are statistically equivalent to those using real money outcomes (Matusiewicz et al., 2013), the use of hypothetical outcomes may fundamentally change the nature of the task (i.e., self-report of preference rather than exhibited behavioral preference). Moreover, we cannot extrapolate the same statistical equivalency between real and hypothetical alcohol outcomes. A third limitation is that we did not consider the diversity of environmental and contextual factors that impact delay discounting. For example, experimental and longitudinal research implicates early rearing/childhood environment on delay discounting (e.g., Felton et al., 2021; Perry et al., 2008). We did not collect measures relevant to this and are not able to consider it or other moderating factors in our analysis or interpretation. A fourth limitation is that the generalizability of the findings may be bounded to the current sample's demographics, which primarily consisted of college-aged White males. Finally, the centrality of delay discounting to the misuse of alcohol (and other substances), as typically implemented in human studies, is not without dispute (e.g., Bailey et al.,

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2021). For example, despite reasonable face validity as rationale for the application of delay discounting paradigms, there remain questions regarding concurrent and discriminant validity of hypothetical money/money tasks and their relevance to actual behavior associated with substance misuse. To the extent that Bailey and colleagues seek to draw attention to tasks that may have more relevance to real-world decisions and are more-strongly associated with clinical phenomena, it appears that the cross-commodity delay discounting tasks implemented in the present study represent a small step in that direction.

Conclusions and Implications

Conventional interpretations of delay discounting based on single-commodity DD tasks have been that individuals who engage in alcohol misuse exhibit a generalized inability or unwillingness to wait for delayed rewards that is particularly exacerbated for alcohol. The present results, utilizing cross-commodity DD tasks, perhaps modify this previous narrative. Suggestive evidence in Moody et al. (2017) indicated the possibility that problematic alcohol use (via AUDIT) may be inversely associated with rate of delay discounting in an immediate money—delayed alcohol task. Naude et al. (2021) provided further indication of this with a significant bivariate correlation between the immediate money—delayed alcohol task and AUDIT, and the dichotomized harmful alcohol use was associated with different rates of delay discounting in the cross-commodity tasks. The present results extend that suggestive evidence with explicit evidence that the immediate money—delayed alcohol DD task provides unique explanatory power associated with past-month alcohol use as well as problematic use.

We observed that individuals with high alcohol-related measures indicated preference for *waiting for delayed alcohol* in cross-commodity DD tasks when the immediate alternative was money. Said a different way, results from the cross-commodity DD tasks reveal that as rates of alcohol use and alcohol-related problems increased, so did relative preference for delayed alcohol in the presence of immediate money. This could be interpreted as an *investment* in access to alcohol in the future. We believe that this is a novel conceptualization that warrants continued investigation.

The conceptualization of preference for alcohol in lieu of alternative commodities across time has been considered in numerous behavioral economic theories of addiction (e.g., Becker & Murphy, 1988; Herrnstein & Prelec, 1992; Rachlin, 2000a; see review in Rachlin, 1997). Specifically, these theories have highlighted the dynamic influence of continued drug use and nonuse on the relative valuation between the drug and competing rewards (i.e., substitutes), including propositions that commodity-specific properties are likely to characterize effective substitutes (Green & Freed, 1993; Green & Fisher, 2000; Rachlin, 2000b). As access to, and contact with, substitutes for drug reward impact short-and long-term substance use trajectories (e.g., Goelz et al., 2014; Schnoll et al., 2016; Smith & Beckmann, 2021), cross-commodity DD tasks may serve as a valuable approach to identify the most effective, health-promoting alternatives to substance misuse, particularly given that the diversity of potential substitutes will have inherent delays to access or different consumption periods (Rachlin, 1992). With the recognition of the significance of competing rewards in problematic alcohol use, prevention and intervention approaches are

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increasingly considering how the valuation and price of substitutes may be more effective than manipulation of the price of the addictive substances themselves (Rachlin, 2007). Continued exploration of the valuation of immediate and delayed access to substances and their substitutes/complements, using cross-commodity DD and other assessments, will be able to greater specify the role of delay in impacting behavior relevant for substance use and misuse. And, we expect the field of behavioral economics to continue to be informed and inspired by the work of Howard Rachlin.

References

Acuff SF, Soltis KE, Dennhardt AA, Berlin KS, & Murphy JG (2018). Evaluating behavioral economic models of heavy drinking among college students. Alcoholism: Clinical and Experimental Research, 42(7), 1304–1314. 10.1111/acer.13774 [PubMed: 29757460]

Amlung M, Vedelago L, Acker J, Balodis I, & MacKillop J (2017). Steep delay discounting and addictive behavior: A meta-analysis of continuous associations. Addiction, 112(1), 51–62. 10.1111/add.13535

Appelbaum M, Cooper H, Kline RB, Mayo-Wilson E, Nezu AM, & Rao SM (2018). Journal article reporting standards for quantitative research in psychology: The APA Publications and Communications Board task force report. American Psychologist, 73(1), 3–25. 10.1037/amp0000191 [PubMed: 29345484]

Babor TF, de la Fuente JR, Saunders J, & Grant M (2001). The alcohol use disorders identification test: Guidelines for use in primary health care. World Health Organization.

Bailey AJ, Romeu RJ, & Finn PR (2021). The problems with delay discounting: A critical review of current practices and clinical applications. Psychological Medicine, 51(11), 1799–1806. 10.1017/S0033291721002282 [PubMed: 34184631]

Baum WM, & Rachlin HC (1969). Choice as time allocation. Journal of the Experimental Analysis of Behavior, 12(6), 861–874. 10.1901/jeab.1969.12-861 [PubMed: 16811415]

Becker GS, & Murphy KM (1988). A theory of rational addiction. Journal of Political Economy, 96(4), 675–700. 10.1086/261558

Bickel WK, Jarmolowicz DP, Mueller ET, & Gatchalian KM (2011). The behavioral economics and neuroeconomics of reinforcer pathologies: Implications for etiology and treatment of addiction. Current Psychiatry Reports, 13(5), 406–415. 10.1007/s11920-011-0215-1 [PubMed: 21732213]

Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, & Murphy JG (2014). The behavioral economics of substance use disorders: Reinforcement pathologies and their repair. Annual Review of Clinical Psychology, 10(1), 641–677. 10.1146/annurev-clinpsy-032813-153724

Bickel WK, Landes RD, Christensen DR, Jackson L, Jones BA, Kurth-Nelson Z, & Redish AD (2011). Single- and cross-commodity discounting among cocaine addicts: The commodity and its temporal location determine discounting rate. Psychopharmacology, 217(2), 177–187. 10.1007/s00213-011-2272-x [PubMed: 21487658]

Brown RA, Burgess ES, Sales SD, Whiteley JA, Evans DM, & Miller IW (1998). Reliability and validity of a smoking timeline follow-back interview. Psychology of Addictive Behaviors, 12(2), 101–112. 10.1037/0893-164X.12.2.101

Burnham KP, Anderson DR, & Huyvaert KP (2011). AIC model selection and multimodel inference in behavioral ecology: Some background, observations, and comparisons. Behavioral Ecology and Sociobiology, 65(1), 23–35. 10.1007/s00265-010-1029-6

Chung S (1965). Effects of delayed reinforcement in a concurrent situation. Journal of the Experimental Analysis of Behavior, 8(6), 439–444. 10.1901/jeab.1965.8-439 [PubMed: 5851405]

Dennhardt AA, & Murphy JG (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), 595–604. 10.1037/a0025807 [PubMed: 21988480]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Estle SJ, Green L, Myerson J, & Holt DD (2007). Discounting of monetary and directly consumable rewards. Psychological Science, 18(1), 58–63. 10.1111/j.1467-9280.2007.01849.x [PubMed: 17362379]

Felton JW, Collado A, Cinader M, Lejuez CW, Chronis-Tuscano A, & Yi R (2021). Exposure to maternal depressive symptoms and growth in adolescent substance use: The mediating role of delay discounting. Development and Psychopathology, 33(4), 1279–1289. 10.1017/S0954579420000486 [PubMed: 32519638]

Goelz PM, Audrain-McGovern JE, Hitsman B, Leone FT, Veluz-Wilkins A, Jepson C, Wileyto EP, D'Avanzo PA, Rivera JG, & Schnoll RA (2014). The association between changes in alternative reinforcers and short-term smoking cessation. Drug and Alcohol Dependence, 138, 67–74. 10.1016/j.drugalcdep.2014.02.007 [PubMed: 24598122]

Green L, & Fisher EB Jr. (2000). Economic substitutability: Some implications for health behavior. In Bickel WK & Vuchinich RE (Eds.), Reframing health behavior change with behavioral economics (pp. 115–144). Lawrence Erlbaum Publishers.

Green L, & Freed DE (1993). The substitutability of reinforcers. Journal of the Experimental Analysis of Behavior, 60(1), 141–158. 10.1901/jeab.1993.60-141 [PubMed: 16812696]

Green L, & Myerson J (2019). On the complexity of discounting, choice situations, and people. Perspectives on Behavior Science, 42(3), 433–443. 10.1007/s40614-019-00209-y [PubMed: 31976443]

Herrnstein RJ, & Prelec D (1992). A theory of addiction. In Loewenstein G & Elster J (Eds.) Choice over time (pp. 331–360). Sage Publications.

Killeen P, Green L, & Neuringer A (2021). Howard Rachlin (1935–2021). American Psychologist, 76(8), Article 1349. 10.1037/amp0000908

Koffarnus MN, & Bickel WK (2014). A 5-trial adjusting delay discounting task: Accurate discount rates in less than one minute. Experimental and Clinical Psychopharmacology, 22(3), 222–228. 10.1037/a0035973 [PubMed: 24708144]

Laibson D, & Zeckhauser R (1998). Amos Tversky and the ascent of behavioral economics. Journal of Risk and Uncertainty, 16(1), 1–41. 10.1023/A:1007717224343

Lemley SM, Kaplan BA, Reed DD, Darden AC, & Jarmolowicz DP (2016). Reinforcer pathologies: Predicting alcohol related problems in college drinking men and women. Drug and Alcohol Dependence, 167, 57–66. 10.1016/j.drugalcdep.2016.07.025 [PubMed: 27515726]

Logan FA (1965). Decision making by rats: Delay versus amount of reward. Journal of Comparative and Physiological Psychology, 59(1), 1–12. 10.1037/h0021633 [PubMed: 14282403]

MacKillop J (2016). The behavioral economics and neuroeconomics of alcohol use disorders. Alcoholism: Clinical and Experimental Research, 40(4), 672–685. 10.1111/acer.13004 [PubMed: 26993151]

MacKillop J, Amlung MT, Few LR, Ray LA, Sweet LH, & Munafò MR (2011). Delayed reward discounting and addictive behavior: A meta-analysis. Psychopharmacology, 216(3), 305–321. 10.1007/s00213-011-2229-0 [PubMed: 21373791]

MacKillop J, Mattson RE, Anderson Mackillop EJ, Castelda BA, & Donovick PJ (2007). Multidimensional assessment of impulsivity in undergraduate hazardous drinkers and controls. Journal of Studies on Alcohol and Drugs, 68(6), 785–788. 10.15288/jsad.2007.68.785 [PubMed: 17960295]

Matusiewicz AK, Carter AE, Landes RD, & Yi R (2013). Statistical equivalence and test–retest reliability of delay and probability discounting using real and hypothetical rewards. Behavioural Processes, 100, 116–122. 10.1016/j.beproc.2013.07.019 [PubMed: 23954833]

Moody LN, Tegge AN, & Bickel WK (2017). Cross-commodity delay discounting of alcohol and money in alcohol users. The Psychological Record, 67(2), 285–292. 10.1007/s40732-017-0245-0 [PubMed: 29056767]

National Institute on Alcohol Abuse and Alcoholism (2020). Drinking levels defined https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/moderate-binge-drinking

Naude GP, Reed DR, Jarmolowicz DP, Martin LE, Fox AT, Strickland JC, & Johnson MW (2021). Single- and cross-commodity discounting among adults who use alcohol and cannabis:

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Associations with tobacco use and clinical indicators. Drug and Alcohol Dependence, 229(Pt. B), Article 109082. 10.1016/j.drugalcdep.2021.109082

Odum AL (2011). Delay discounting: I'm a k, you're a k. Journal of the Experimental Analysis of Behavior, 96(3), 427–439. 10.1901/jeab.2011.96-423 [PubMed: 22084499]

Odum AL, Becker RJ, Haynes JM, Galizio A, Frye CCJ, Downey H, Friedel JE, & Perez DM (2020). Delay discounting of different outcomes: Review and theory. Journal of the Experimental Analysis ofBehavior, 113(3), 657–679. 10.1002/jeab.589

Parke CS (2013). Module 5: Identifying and addressing outliers. In Essential first steps to data analysis: Scenario-based examples using SPSS (pp. 81–102). SAGE Publications. 10.4135/9781506335148

Pericot-Valverde I, Yoon JH, & Gaalema DE (2020). Single- and cross-commodity delay discounting of money and e-cigarette liquid in experienced e-cigarette users. Drug and Alcohol Dependence, 206, Article 107740. 10.1016/j.drugalcdep.2019.107740

Perry JL, Stairs DJ, & Bardo MT (2008). Impulsive choice and environmental enrichment: Effects of d-amphetamine and methylpheni-date. Behavioural Brain Research, 193(1), 48–54. 10.1016/j.bbr.2008.04.019 [PubMed: 18534693]

Petry NM (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. Psychopharmacology, 154(3), 243–250. 10.1007/s002130000638 [PubMed: 11351931]

Phung QH, Snider SE, Tegge AN, & Bickel WK (2019). Willing to work but not to wait: Individuals with greater alcohol use disorder show increased delay discounting across commodities and less effort discounting for alcohol. Alcoholism: Clinical and Experimental Research, 43(5), 927–936. 10.1111/acer.13996 [PubMed: 30817019]

Pritschmann RK, Yurasek AM, & Yi R (2021). A review of cross-commodity delay discounting research with relevance to addiction. Behavioural Processes, 186, Article 104339. 10.1016/j.beproc.2021.104339

Rachlin H (1992). Diminishing marginal value as delay discounting. Journal of the Experimental Analysis of Behavior, 57(3), 407–415. 10.1901/jeab.1992.57-407 [PubMed: 1602271]

Rachlin H (1995). Behavioral economics without anomalies. Journal of the Experimental Analysis of Behavior, 64(3), 397–404. 10.1901/jeab.1995.64-397 [PubMed: 8551195]

Rachlin H (1997). Four teleological theories of addiction. Psychonomic Bulletin & Review, 4(4), 462–473. 10.3758/BF03214335

Rachlin H (2000a). The science of self-control. Harvard University Press.

Rachlin H (2000b). The lonely addict. In Bickel WK & Vuchinich RE (Eds.), Reframing health behavior change with behavioral economics (pp. 145–164). Lawrence Erlbaum.

Rachlin H (2007). In what sense are addicts irrational? Drug and Alcohol Dependence, 90(Suppl. 1), S92–S99. 10.1016/j.drugalcdep.2006.07.011 [PubMed: 16956732]

Rachlin H, Kagel JH, & Battalio RC (1980). Substitutability in time allocation. Psychological Review, 87(4), 355–374. 10.1037/0033-295X.87.4.355

Rachlin H, Logue AW, Gibbon J, & Frankel M (1986). Cognition and behavior in studies of choice. Psychological Review, 93(1), 33–35. 10.1037/0033-295X.93.1.33

Raineri A, & Rachlin H (1993). The effect of temporal constraints on the value of money and other commodities. Journal of Behavioral Decision Making, 6(2), 77–94. 10.1002/bdm.3960060202

Saunders JB, Aasland OG, Babor TF, de la Fuente JR, & Grant M (1993). Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption—II. Addiction, 88(6), 791–804. 10.1111/j.1360-0443.1993.tb02093.x [PubMed: 8329970]

Schnoll RA, Hitsman B, Blazekovic S, Veluz-Wilkins A, Wileyto EP, Leone FT, & Audrain-McGovern JE (2016). Longitudinal changes in smoking abstinence symptoms and alternative reinforcers predict long-term smoking cessation outcomes. Drug and Alcohol Dependence, 165, 245–252. 10.1016/j.drugalcdep.2016.06.017 [PubMed: 27372219]

Smith AP, & Beckmann JS (2021). Quantifying value-based determinants of drug and non-drug decision dynamics. Psychopharmacology, 238(8), 2047–2057. 10.1007/s00213-021-05830-x [PubMed: 33839902]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Sobell LC, & Sobell MB (1992). Timeline follow-back: A technique for assessing self-repoamarted alcohol consumption. In Litten RZ & Allen JP (Eds.), Measuring alcohol consumption: Psychosocial and biochemical methods (pp. 41–72). Humana Press. 10.1007/978-1-4612-0357-5_3

Stanger C, Ryan SR, Fu H, Landes RD, Jones BA, Bickel WK, & Budney AJ (2012). Delay discounting predicts adolescent substance abuse treatment outcome. Experimental and Clinical Psychopharmacology, 20(3), 205–212. 10.1037/a0026543 [PubMed: 22182419]

Stein JS, Sze YY, Athamneh L, Koffarnus MN, Epstein LH, & Bickel WK (2017). Think fast: Rapid assessment of the effects of episodic future thinking on delay discounting in overweight/obese participants. Journal of Behavioral Medicine, 40(5), 832–838. 10.1007/s10865-017-9857-8 [PubMed: 28508382]

Stojek MM, Fischer S, Murphy CM, & MacKillop J (2014). The role of impulsivity traits and delayed reward discounting in dysregulated eating and drinking among heavy drinkers. Appetite, 80, 81–88. 10.1016/j.appet.2014.05.004 [PubMed: 24816318]

Strickland JC, Lee DC, Vandrey R, & Johnson MW (2021). A systematic review and meta-analysis of delay discounting and cannabis use. Experimental and Clinical Psychopharmacology, 29(6), 696–710. 10.1037/pha0000378 [PubMed: 32309968]

Stuppy-Sullivan AM, Tormohlen KN, & Yi R (2016). Exchanging the liquidity hypothesis: Delay discounting of money and self-relevant non-money rewards. Behavioural Processes, 122, 16–20. 10.1016/j.beproc.2015.11.006 [PubMed: 26556504]

Vuchinich RE, & Simpson CA (1998). Hyperbolic temporal discounting in social drinkers and problem drinkers. Experimental and Clinical Psychopharmacology, 6(3), 292–305. 10.1037/1064-1297.6.3.292 [PubMed: 9725113]

Wesley MJ, Lohrenz T, Koffarnus MN, McClure SM, De La Garza R II, Salas R, Thompson-Lake DG, Newton TF, Bickel WK, & Montague PR (2014). Choosing money over drugs: The neural underpinnings of difficult choice in chronic cocaine users. Journal of Addiction, 2014, Article 189853. 10.1155/2014/189853

Yankelevitz RL, Mitchell SH, & Zhang Y (2012). Gender differences in factors associated with alcohol drinking: Delay discounting and perception of others' drinking. Drug and Alcohol Dependence, 123(1–3), 273–276. 10.1016/j.drugalcdep.2011.11.012 [PubMed: 22154359]

Yi R, Mitchell SH, & Bickel WK (2010). Delay discounting and substance abuse-dependence. In Madden GJ & Bickel WK (Eds.), Impulsivity: The behavioral and neurological science of discounting (pp. 191–211). American Psychological Association. 10.1037/12069-007

Yoon JH, & Higgins ST (2008). Turning k on its head: Comments on use of an ED50 in delay discounting research. Drug and Alcohol Dependence, 95(1–2), 169–172. 10.1016/j.drugalcdep.2007.12.011 [PubMed: 18243583]

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Public Health Significance Statement

Understanding and reducing hazardous drinking by young adults remains a public health priority. This study highlights the utility of cross-commodity delay discounting tasks in understanding associations between alcohol use/misuse and intertemporal choice by young adults who engage in hazardous drinking. Specifically, we find that lower rates of delay discounting when money is immediately available and alcohol is available following a delay (indicative of relative preference for delayed alcohol) is associated with greater past-month alcohol use and hazardous drinking. This result is inconsistent with single-commodity delay discounting literature that implies that problematic alcohol use is associated with a general unwillingness or inability to delay gratification. The present results suggest that individuals who engage in problematic alcohol use may invest in future access to alcohol, with implications for the etiology of alcohol use disorder as well as for behavioral interventions that seek to alter valuation of commodities across time.

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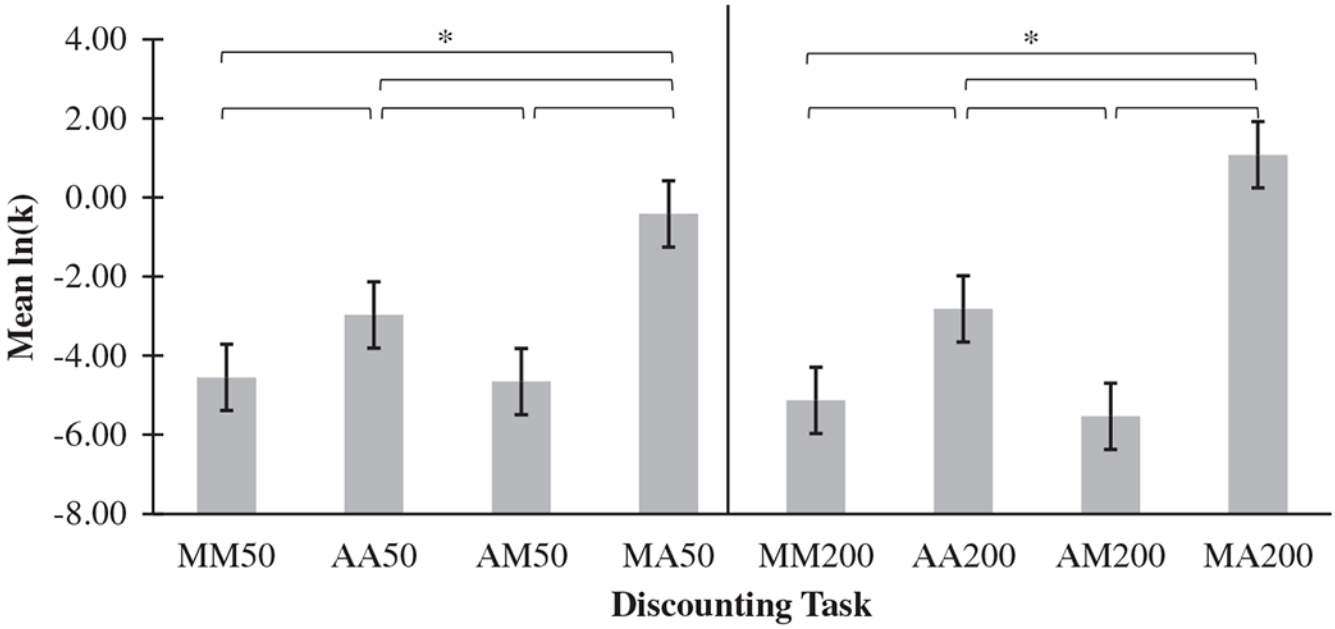

Figure 1. Mean DD Rates With Standard Error

Note. DD = Delay discounting; HSD = honest significant difference.

* Indicates significant Tukey's HSD pair-wise comparison at a $p < .05$ level.

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Table 1

Eight Discounting Tasks

	Delayed outcome			
Immediate outcome	**Alcohol ($50)**	**Money ($50)**	**Alcohol ($200)**	**Money ($200)**
Alcohol	AA50	AM50	AA200	AM200
Money	MA50	MM50	MA200	MA200

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Table 2

Sample Demographics as Frequencies of the Sample (Percentages of the Sample in Parentheses)

Sample demographics (*N* = 70)	Frequency (%)
Age	
Under 21	39 (55.7)
21 or older	31 (44.3)
Sex	
Female	20 (28.6)
Male	50 (71.4)
Race[a]	
White	56 (80.0)
Asian	10 (14.3)
Black	3 (4.3)
Other	6 (8.5)
Ethnicity	
Hispanic or Latino	10 (14.3)
Not Hispanic or Latino	60 (85.7)
Year in undergraduate school	
Freshman	28 (40.0)
Sophomore	16 (22.9)
Junior	15 (21.4)
Senior	11 (15.7)
Employment status	
Employed part-time	31 (44.3)
Unemployed/full-time student	39 (55.7)
Annual income	
Less than $10,000	62 (88.6)
$10,000 or above	8 (11.4)

[a]Participants were instructed to select all applicable races to include individuals of mixed race; therefore, the total sample percentage exceeds 100%.

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Table 3

Correlations Among Study Constructs

Construct	1	2	3	4	5	6	7	8	9	10
1. MM50	—									
2. MM200	0.845**	—								
3. AA50	0.522**	0.438**	—							
4. AA200	0.442**	0.457**	0.719**	—						
5. AM50	0.769**	0.712**	0.612**	0.401**	—					
6. AM200	0.776**	0.795**	0.329**	0.179	0.708**	—				
7. MA50	0.025	0.032	0.056	0.126	−0.022	−0.084	—			
8. MA200	−0.088	−0.018	0.195	0.253*	−0.012	−0.190	0.430**	—		
9. AUDIT	0.188	0.120	0.118	−0.072	0.272*	0.238	−0.296*	−0.062	—	
10. Alcohol Consumption	0.174	0.188	0.029	0.112	0.208	0.201	−0.253*	−0.011	0.550*	—

Note. AUDIT = alcohol use disorders identification test; TLFB = timeline follow-back. Alcohol consumption = total standard drinks consumed in the past 30 days (assessed via the TLFB).

* $p < .05$, two-tailed.

** $p < .01$, two-tailed.

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Table 4

Results of Multiple Regression Analyses for Discounting Rates Predicting Alcohol Use

						95% CI	
Magnitude	**Alcohol use measure**	***t***	***p***	**β**	**Std. error**	**LL**	**UL**
$50			AUDIT				
	MM50	−0.094	.924	−0.005	0.052	−0.109	0.099
	AA50	−0.305	.762	−0.007	0.022	−0.050	0.036
	AM50	1.581	.119	0.078	0.049	−0.021	0.177
	MA50	−2.505	.015*	−0.042	0.017	−0.075	−0.008
			Alcohol consumption				
	MM50	0.424	.673	0.031	0.073	−0.114	0.176
	AA50	−0.923	.360	−0.028	0.030	−0.088	0.032
	AM50	01.142	.257	0.079	0.069	−0.059	0.217
	MA50	−2.072	.042*	−0.048	0.023	−0.095	−0.002
$200			AUDIT				
	MM200	−0.524	.602	−0.034	0.066	−0.165	0.097
	AA200	−0.574	.568	−0.012	0.020	−0.052	0.029
	AM200	1.640	.106	0.100	0.061	−0.022	0.222
	MA200	0.194	.847	0.004	0.018	−0.033	0.040
			Alcohol consumption				
	MM200	0.051	.960	0.005	0.095	−0.185	0.195
	AA200	0.484	.630	0.014	0.029	−0.045	0.073
	AM200	0.812	.420	0.072	0.089	−0.105	0.250
	MA200	0.040	.969	0.001	0.026	−0.052	0.054

Note. AUDIT = alcohol use disorders identification test; CI = confidence interval; Std. error = standard error; LL = lower limit; UL = upper limit.

*Indicates significant at a $p < .05$ level.

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Table 5

AIC Values for Model Comparisons—$50 Magnitude

			AUDIT		Alcohol consumption	
Class	**Model**	**Predictors**	**AIC**	**AUDIT rank**	**AIC**	**AC rank**
Single predictors	1	MM50	96.33	3[a]	139.01	3
	2	AA50	99.17	4[a]	147.40	4[a]
	3	**AM50**	**93.80**	1	138.36	2
	4	**MA50**	93.93	**2**	**137.98**	**1**
Double predictors	5	MM50, AA50	102.20	6[a]	143.92	5[a]
	6	MM50, AM50	97.75	3[a]	141.70	3[a]
	7	MM50, MA50	95.99	2[a]	139.89	2
	8	AA50, AM50	99.32	5[a]	142.41	4[a]
	9	AA50, MA50	98.85	4[a]	145.48	6[a]
	10	**AM50, MA50**	**93.72**	**1**	**139.53**	**1**
Triple predictors	11	MM50, AA50, AM50	101.28	3[a]	145.69	4[a]
	12	MM50, AA50, MA50	101.87	4[a]	144.96	3[a]
	13	**MM50, AM50, MA50**	**97.81**	**1**	**142.84**	**1**
	14	AA50, AM50, MA50	99.49	2[a]	143.93	2
Quadruple predictors	**15**	**MM50, AA50, AM50, MA50**	**103.56**		**147.16**	

Note. AIC = Akaike information criterion; AUDIT = alcohol use disorders identification test; AC = alcohol consumption. For each alcohol use measure, the best interclass AIC scores are in bold.

[a]Denotes an unpreferred model relative to the best-performing model.

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Table 6

AIC for Model Comparisons—$200 Magnitude

			AUDIT		Alcohol consumption	
Class	**Model**	**Predictors**	**AIC**	**AUDIT rank**	**AIC**	**AC rank**
Single predictors	1	MM200	89.96	4[a]	139.95	4[a]
	2	AA200	89.01	2[a]	135.91	2[a]
	3	**AM200**	**84.05**	**1**	**132.58**	**1**
	4	MA200	89.04	3[a]	136.68	3[a]
Double predictors	5	MM200, AA200	91.72	4[a]	138.30	4
	6	**MM200, AM200**	**87.11**	**1**	**135.66**	**1**
	7	MM200, MA200	93.01	5[a]	138.53	5[a]
	8	AA200, AM200	89.46	2[a]	137.79	2[a]
	9	AA200, MA200	95.08	6[a]	141.30	6[a]
	10	AM200, MA200	90.32	3[a]	138.08	3[a]
Triple predictors	**11**	**MM200, AA200, AM200**	**92.84**	**1**	**140.68**	**1**
	12	MM200, AA200, MA200	97.89	4[a]	143.77	4[a]
	13	MM200, AM200, MA200	93.35	2	141.13	2
	14	AA200, AM200, MA200	95.64	3[a]	143.24	3
Quadruple predictors	**15**	**MM200, AA200, AM200, MA200**	**98.98**		**146.11**	

Note. AIC = Akaike information criterion; AUDIT = alcohol use disorders identification test; AC = alcohol consumption. For each alcohol use measure, the best interclass AIC scores are in bold.

[a]Denotes an unpreferred model relative to the best-performing model.