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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

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Abstract

Background—Delay discounting refers to the devaluation of a reward given increasing delays to delivery. Similarly, effort discounting refers to the devaluation of a reward given increasing effort required to obtain it. Individuals with substance use disorder show higher rates of delay discounting, exacerbating short-term positive reinforcement at the expense of long-term consequences. This study explores how effort discounting compares to delay discounting behavior among alcohol users as well as how these preferences change between monetary and alcohol rewards.

Methods—100 participants completed an online survey through Amazon Mechanical Turk. Participant alcohol use was evaluated using DSM 5 and AUDIT criteria. All participants completed four randomized discounting tasks involving delay or effort discounting, in which the reward was money or alcohol. A follow-up experiment (n = 423) added the alcohol purchase task to assess alcohol valuation.

Results—Individuals with greater alcohol use disorder (AUD) severity discounted future money and alcohol significantly more than those with less AUD. However, individuals meeting more DSM-5 criteria were only willing to perform more effort for alcohol. The follow-up experiment replicated these findings and demonstrated that individuals with greater AUD also showed an increased valuation of alcohol and alcohol value mediated effort discounting.

Conclusions—These results suggest that individuals with greater AUD were less willing to wait for money or alcohol. While all participants were willing to work for money regardless of AUD severity, individuals with greater AUD showed increased valuation of alcohol drinks and were

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CONFLICTS OF INTEREST

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willing to exert more effort to obtain alcohol. Together, these results paint a picture of individuals with increased AUD as both more impulsive and willing to work to obtain alcohol, contributing to our understanding of decision-making among individuals who abuse substances.

Keywords

Effort Discounting; Delay Discounting; Behavioral Economics; Decision-Making; Alcohol Use Disorder; Alcohol Purchase Task

INTRODUCTION

Understanding decision-making and why individuals make certain choices is a growing, multifaceted avenue of research. One type of decision-making, delay discounting, refers to the rate of devaluation of a reward anticipating delayed receipt of that reward. That is, an individual with a high rate of delay discounting behavior is more likely to choose a small reward sooner than wait for a larger reward later. Some researchers have suggested that delay discounting is a personal trait that may play a role in negative decision-making across a number of maladaptive behaviors (Odum, 2011, Bickel et al., 2012, Bickel, 2015). Furthermore, numerous studies have shown that individuals who are dependent on substances have increased delay discounting (Bickel and Marsch, 2001, Yi et al., 2010, MacKillop et al., 2011, Amlung et al., 2017). In particular, individuals with alcohol use disorder have been shown to have greater discounting rates for money and alcoholic rewards compared to individuals without alcohol abuse (Petry, 2001). In fact, delay discounting has been proposed as a behavioral marker for not only identifying current substance use and assessing severity, but also predicting future use and treatment outcomes (Bickel et al., 2014). Although delay discounting and substance use disorder has been relatively well-studied, less is known about substance abuse and *effort* discounting.

Consistent with delay discounting, effort discounting refers to the rate of devaluation of a reward with increased amount of effort required to obtain that reward. Therefore, an individual exhibiting higher effort discounting would be less likely to make choices requiring larger amounts of effort, and instead prefer a smaller reward for zero or little effort. Conversely, individuals with lower effort discounting would be more willing to engage in work to obtain certain rewards. Some studies have suggested that alteration of neuronal pathways, via hormones or lesions, can alter effort discounting preferences in animal models (Denk et al., 2005, Walton et al., 2002). For example, one study showed that rats who previously chose to climb a barrier to obtain a large reward, chose a smaller reward with no barrier after surgical lesions to the medial front cortex. These choices could further be altered by lowering the barrier or increasing the reward in the large reward option (Walton et al., 2002), suggesting that an insult to an organism's brain (e.g., lesions or chronic alcohol administration) may alter effort-based decision-making preferences.

Effort discounting occurs with multiple types of tasks in a wide range of participants, and devaluation of a reward can result from both physical or mental effort (Ostaszewski et al., 2013). For example, one study found that healthy young adults discounted more steeply on an effort discounting task of typing strings of letters backwards when sleep deprived,

however they demonstrated no change in their delay discounting rates. These results suggested to the authors that delay and effort discounting have differing underlying mechanisms (Libedinsky et al., 2013). Consistently, deprived cigarette smokers demonstrated increased effort discounting preferring immediately available cigarettes over effort to obtain $10, whereas delay discounting preferences for monetary rewards did not change (Mitchell, 2004). Although possibly acting through differential mechanisms, several studies have suggested a positive relationship between effort and delay discounting (Mitchell, 1999, Botvinick et al., 2009). While one study did not find differences in effort discounting for a monetary reward between regular smokers and non-smokers (Mitchell, 1999), to our knowledge effort discounting has not been demonstrated in individuals with alcohol use disorder.

The present set of experiments sought to assess how individuals with alcohol use disorder discount monetary and alcohol rewards when they were either delayed or required effort to obtain them (i.e., typing words), and how their discount rates in those conditions differ on a AUD use severity continuum. We hypothesized that discounting rates in both delay and effort discounting tasks, for both money and alcohol, would be higher in individuals with greater severity of alcohol use disorder.

EXPERIMENT 1

Experiment 1 aimed to explore whether individuals who abuse alcohol have different effort discounting than individuals with less alcohol use. If so, we wanted to understand how this behavior compared to delay discounting and whether or not effort discounting changes with different commodities (i.e., money or alcoholic beverages).

Methods

Participants—A total of 100 participants, who were U.S. registrants of Amazon Mechanical Turk, completed this study. Eligibility requirements included being at least 18 years old, being located in the United States, and having a human intelligence task (HIT) approval rating of at least 90 percent. Participants also completed two prescreening questions to determine eligibility. Inclusion criteria required that participants, 1) report drinking alcohol and 2) were not an employee at Virginia Tech.

Three validation questions were included throughout to ensure thoughtful responses. To be included in the final dataset, participants needed to correctly answer at least two out of three validation questions. These validation questions involved 1) typing out a 50-word sample prompt provided to them, 2) recalling the number of words on a standard, double-spaced page, and 3) answering for the immediate option when asked to choose between $100 now versus $50 in three weeks. All three of these questions were reasonably answerable if the participants were attending to the survey and reading carefully. For example, participants were reminded on each page of the effort discounting tasks that the number of words on a double-spaced sheet of paper was approximately 250. For the third to last set of questions in the survey, we asked participants to recall that number; their response was considered correct if they were within 50 words (i.e. 200–300 words). None of the participants needed

to be removed based on these criteria. No personally identifiable data were collected. This study was reviewed and approved by the Virginia Tech Institutional Review Board.

Procedures—Participants provided general demographic information (age, gender, education, income, and race), then completed questionnaires and tasks described below.

Tasks—Alcohol use: All participants answered questions regarding their alcohol use from the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM 5) (American Psychiatric Association, 2013) and the Alcohol Use Disorders Identification Test (AUDIT) (Saunders et al., 1993) to assess alcohol use disorder criteria and misuse, respectively. Although it is recommended to evaluate DSM 5 criteria in an interview setting with a trained professional, in order to assess these criteria through mTurk, participants provided a response to each criteria online. Supplement 1 provides the language for each of the DSM 5 criteria used. The total number of "yes" responses indicated met DSM 5 criteria, with more indicating greater alcohol use severity.

Computer use: Participants answered a total of seven questions regarding their computer use, including participant's number of hours typically spent using a computer each day, whether their work required the use of a computer, the participant's self-rated typing speed, their self-rated typing proficiency, how many fingers they use to type, the kind of keyboard they typically use, and self-report of any motor impairment or illness that limit their ability to type. Participants were asked to type a short paragraph, which was provided within the survey. After this task, participants were notified that the text consisted of 50 words, which served as a reference for later tasks.

Discounting tasks: All participants completed each of the following tasks, provided in a randomized order.

1. Delay discounting for monetary reward: Participants completed a 5-trial adjusting delay task, which is a rapid (5 trial) task used to assess a participant's delay discounting rate (Koffarnus and Bickel, 2014). The first choice presented the option of receiving $50 now or $100 in 3 weeks. The participant's response to this question adjusted the time delay in the next trial, while the dollar amount of both rewards remained the same. The participants' choice on the final trial determined their ED50 and ln(k) value (Koffarnus and Bickel, 2014).
2. Effort discounting for monetary reward: We adapted the 5-trial adjusting delay task by converting each hour in the delay discounting task into one word that participants would hypothetically have to type (i.e., effort) to receive a reward (e.g. a one hour delay was equivalent to typing one word; a one day delay was equivalent to 24 words, etc.). As a result, the first question presented the option of receiving $50 for typing zero words or $100 for typing 504 words. For reference, participants were asked to actually type a 50 word excerpt of text (see above) from which they could extrapolate the effort required. Additionally, we provided text noting that one standard, double-spaced page typically contains about 250 words, 10 pages contain 2,500 words, etc.

3. Delay discounting for alcohol reward: This task mirrored the delay discounting for monetary reward task, however participants were asked to choose between receiving a smaller amount of alcohol now, or a larger amount of alcohol after some delay. During an "Alcohol use" portion of the survey, we asked participants how many standard size alcoholic beverages they considered to be equivalent in value to $100. The number of drinks they selected and half this value were utilized as the participant's reward options for the task. For example, if a participant said that 20 alcoholic drinks were equivalent to $100, the first question in this task presented participants the choice between receiving 10 drinks now or 20 drinks in 3 weeks.

4. Effort discounting for alcohol reward: This task combined the adaptations from the effort discounting for monetary reward task and delay discounting for alcohol reward. That is, the amount of drinks offered as a reward in this task was based on the participant's response regarding how many alcoholic beverages are equivalent to $100 (as described in the "delay discounting for alcohol reward" task above). However, instead of a delay, the participants were asked to indicate their preference for the amount of effort they would perform to obtain the drinks. For example, if participants said that 20 alcoholic drinks were equivalent to $100, the first question in this task would present the choice of receiving 10 drinks for typing zero words or 20 drinks for typing 504 words.

Overall, these discounting tasks were designed to be comparable to one another. For example, we adjusted the number of words participants would have to hypothetically type in the effort discounting task to proportionally match the rate of change in the delays of the delay discounting tasks. That is, words typed were equivalent to hours of delays. Of note, the ln(k) value for the five-trial adjusting delay discounting tasks is derived on a scale of days (Koffarnus and Bickel, 2014), while our effort discounting task used a scale of hours. Therefore, to equate the scales for data analysis, we adjusted the ED50 value output in the delay discounting tasks, by multiplying by 24 to make the ln(k) values comparable across tasks.

Data analysis—DSM 5 scores were calculated by summing the "yes" responses from the 11 DSM 5 criteria for alcohol use disorder (AUD) (American Psychiatric Association, 2013). Discounting rates (ln(k)s) were compared to DSM 5 scores using Pearson correlational analysis. DSM 5 scores were also correlated with AUDIT scores to check for consistency. Analyses were conducted using GraphPad Prism 7 (GraphPad Software, La Jolla, California, USA) and R Core Team (2017).

Results

Figure 1 summarizes the results of this study, showing Pearson correlations between the four discounting tasks and DSM 5 scores. Individuals with higher DSM 5 scores, and therefore, greater AUD severity, discounted future monetary rewards significantly more than those with lower DSM scores ($r = 0.41$; $p < 0.0001$; Panel A). No significant relationship emerged between DSM 5 scores and effort for monetary rewards ($r = 0.07$; $p = 0.52$; Panel B). When the reward was alcohol, users with higher DSM scores showed greater delay discounting (r =

0.33; $p < 0.001$; Panel C). However, when the reward was alcohol for hypothetical effort, individuals with higher DSM scores and more AUD had less effort discounting ($r = -0.25$; $p = 0.01$; Panel D), suggesting that they would be more willing to type many words to receive more beverages.

Table 1, expands on these results, showing the Pearson r correlation values between the discounting tasks and DSM 5 as well as AUDIT scores. Consistent with the relationship to DSM 5 criteria, delay discounting for money and alcohol was positively correlated with AUDIT scores, while effort discounting was negatively correlated with AUDIT. No statistically significant relationship was observed between effort discounting for money and AUDIT, suggesting a robust effect of alcohol use severity impacting delay and effort discounting differentially.

When comparing across discounting task types, an unpaired t-test revealed that participants discounted alcoholic beverages more than money as a reward ($p = < 0.0001$). That is, overall, participants were more willing to work or wait for money than they were for alcohol, suggesting a difference in commodities.

Discussion

Experiment 1 found that participants with greater AUD severity demonstrate increased delay discounting for monetary rewards. This finding is consistent with previous studies and meta-analyses that have found increased delay discounting, suggesting greater impulsivity and loss of control, in populations who abuse substances (Bickel and Marsch, 2001, Reynolds, 2006, MacKillop et al., 2011, Amlung et al., 2017). Additionally, individuals with greater alcohol use severity showed increased delay discounting when alcohol was offered as a reward, suggesting that this behavior persists across commodities. This finding is also consistent with existing literature that has shown that individuals with alcohol dependence are more impulsive and show higher discounting rates for both money and alcoholic drinks compared to control populations (Petry, 2001). Moreover, these individuals also demonstrated steeper discounting for alcohol over monetary rewards replicating the commodity effect (Bickel et al., 1999, Madden et al., 1999).

Two novel findings in this experiment, however, were that 1) DSM 5 and AUDIT scores, and therefore AUD severity, was not significantly correlated with effort discounting for monetary rewards; individuals across alcohol use levels were similarly willing to work (i.e., hypothetically type words) for money, and 2) DSM 5 and AUDIT scores were negatively correlated with alcohol effort discounting, meaning that individuals with greater AUD severity were more willing to work when the reward was alcohol. These findings suggest that populations who abuse substances demonstrate different effort discounting behaviors between commodities, with increased willingness to work for their drug of choice. This theme of differential discounting preferences across different commodities is reflected in another study that found that smokers who abstained from nicotine for 24 hours had increased impulsive decision-making for drug-related choices, but did not show the same changes with monetary-related choices (Mitchell, 2004).

EXPERIMENT 2

A question emerged that perhaps an individual is more willing to work for alcoholic drinks, if his or her perceived value of those drinks is higher. To answer this question, behavioral economic demand can be used to measure alcohol valuation (Hursh, 1984, Hursh and Silberberg, 2008, Murphy and MacKillop, 2006). The hypothetical alcohol purchase task is often used to assess individual's demand for alcohol (MacKillop et al., 2010, Murphy and MacKillop, 2006). The alcohol purchase task-generated demand curve offers specific information about demand for alcohol, including initial consumption for a commodity at no cost to the subject (Q_0) and sensitivity in purchasing a commodity with increasing price (alpha) (Hursh, 1984, Hursh and Silberberg, 2008). In Experiment 2, we repeated Experiment 1 with identical procedures with the addition of a hypothetical alcohol purchase task to assess the extent to which alcohol valuation was associated with willingness to expend effort to obtain alcoholic drinks.

Methods

A total of 423 participants completed the survey conducted on Amazon's mTurk. Of these subjects, four participants were removed from the data for not successfully answering at least two out of three validation questions (see Methods of Experiment 1). Experiment 2 used the same protocol and survey as Experiment 1, with the addition of an alcohol purchase task. Eight additional participants were removed from the analysis based on exclusion criteria for the alcohol purchase task (Stein et al., 2015), resulting in a total of 411 individuals who were used in the final analysis of this experiment.

Alcohol Purchase Task: Participants were asked to imagine being in a bar with their friends from 9 PM to 2 AM to see a band. In this scenario, they were asked how many standard-sized alcoholic beverages they would purchase for the night at increasing prices (Murphy et al., 2009). The proposed drink prices increased with each subsequent question (i.e., $0, 0.31, 0.63, 1.25, 2.50, 5, 7.50, 10, 15, 20, 40, 80, 160).

Data analysis—The correlational analyses were conducted identically to Experiment 1. That is, DSM scores were again calculated by summing the results from the 11 DSM 5 criteria for alcohol use disorder (AUD) (American Psychiatric Association, 2013). Discounting rates (ln(k)s) were compared to DSM 5 scores using Pearson correlational analysis. Results were further correlated with AUDIT scores to check for consistency. Alcohol purchase task data was analyzed by fitting the data to the exponentiated demand model (Koffarnus et al., 2015) and individual Q_0 and alpha scores were obtained. Analyses were conducted using GraphPad Prism 7 (GraphPad Software, La Jolla, California, USA) and R Core Team (2017).

Mediation analysis—Mediation analyses were conducted using practices outlined in MacKinnon et al (MacKinnon et al., 2007). Briefly, a mediating effect requires the following three linkages: 1) the independent variable (X) predicts the dependent variable (Y), 2) the independent variable predicts the mediator variable (M), and 3) when the dependent variable is regressed on both the independent and mediator variables, the mediator is a significant predictor of the dependent variable while the independent variable's prediction is reduced

(Baron and Kenny, 1986, MacKinnon et al., 2007). Here, we performed two separate mediation analyses to test the mediating effect of demand on the relationship between AUD (X) and effort discounting (Y). In one analysis, we used Q_0 as a representation of demand intensity; in a separate analysis we used alpha to represent demand elasticity. The mediation analyses were performed using the lavaan package in R (Rosseel, 2012). All results from the mediation analyses were reported as standardized estimates.

Results

Figure 2 replicates the findings from Experiment 1 showing the correlations between the four discounting tasks and DSM 5 criteria. Individuals meeting more DSM 5 criteria, and therefore greater AUD severity, had greater delay discounting for money ($r = 0.16$; $p = 0.001$; Panel A). No significant relationship emerged between DSM score and effort discounting for a monetary reward ($r = -0.06$; $p = 0.22$; Panel B). Participants with greater DSM 5 criteria also showed increased delay discounting for alcohol ($r = 0.28$; $p < 0.0001$; Panel C). However, DSM 5 criteria were again negatively associated with effort discounting for alcohol, meaning individuals with greater AUD would be more willing to work for alcohol ($r = -0.15$; $p = 0.002$; Panel D). Overall, these results are consistent with the findings presented in Experiment 1.

Table 2 expands on these findings by summarizing the Pearson r values from the correlation analyses of the discounting tasks, DSM 5 criteria, AUDIT scores, and demand parameters (Q_0 and alpha). As in Experiment 1, the AUDIT scores also replicated the results of the DSM 5 criteria. Both demand parameters, Q_0 and alpha, were significantly correlated with alcohol use severity. That is, Q_0 (how many drinks an individual would hypothetically purchase if they were free), was positively correlated with both DSM 5 criteria ($r = 0.37$; $p < 0.0001$) and AUDIT scores ($r = 0.43$; $p < 0.0001$). Moreover, alpha (a measure of an individual's sensitivity to increasing price) was negatively correlated, as expected, to both DSM 5 criteria ($r = -0.16$; $p = 0.001$) and AUDIT scores ($r = -0.20$; $p < 0.0001$). Q_0 was also significantly negatively correlated with effort discounting $\ln(k)$'s for both monetary ($r = -0.14$; $p = 0.006$) and alcohol rewards ($r = -0.19$; $p < 0.0002$). Whereas, alpha was positively correlated with effort discounting $\ln(k)$'s for both monetary ($r = 0.22$; $p < 0.0001$) and alcohol rewards ($r = 0.14$; $p = 0.005$).

We also analyzed the delay discounting data in both Experiment 1 and 2 to see how they may correlate with demographic variables such as age, gender, computer hours, typing proficiency, etc. With Bonferroni correction for multiple comparisons, these variables were not significantly correlated with the discounting tasks.

We conducted two separate mediation analyses to explore how our demand parameters (Q_0 and alpha) influenced the relationship between alcohol use disorder and effort discounting for alcohol (Preacher and Hayes, 2004, MacKinnon et al., 2007). To assess each component of the mediation model, multiple regression analyses were performed as outlined in Figure 3. First, we evaluated the role of Q_0 in mediating the relationship between DSM score and effort discounting (Figure 3A). DSM score was negatively associated with effort discounting for alcohol (standardized $\beta = -0.148$, $p = 0.002$) and positively correlated with Q_0 (standardized $\beta = 0.370$, $p < 0.001$). Q_0 was negatively correlated with effort discounting for

alcohol (standardized β = −0.151, p = 0.004). Since both the pathways between AUD and Q_0 as well as between Q_0 and effort discounting were significant, there was evidence for a mediating effect of Q_0. Furthermore, a significant indirect effect for Q_0 on the relationship between AUD and effort discounting in alcohol was identified (standardized indirect effect = −0.056, p=0.006). Overall, Q_0 represented 37.8% of the total effect between AUD and effort discounting for alcohol.

In addition, alpha, a measure for price sensitivity, was independently examined with a mediation analysis. DSM score was negatively related to alpha (standardized β = −0.162, p = 0.001). However, alpha was not significantly associated with effort discounting for alcohol (standardized β =0.117, p = 0.018). Alpha represented 12.8% of the total effect; however, the total indirect effort of alpha was not significant (standardized indirect effect = −0.019, p=0.053).

Discussion

Overall, Experiment 2 replicated the results from Experiment 1 and suggested that demand for alcohol is related to those effects. First, individuals with meeting more DSM 5 criteria for alcohol use severity had higher demand for alcohol. Both DSM 5 criteria and AUDIT scores were significantly and positively correlated with initial purchase behavior (Q_0), showing higher initial demand for alcohol with greater alcohol abuse. Second, alpha, a measure for demand elasticity, was significantly and negatively correlated with DSM 5 criteria and AUDIT, showing that participants with greater alcohol abuse severity had more inelastic demand for alcohol (i.e. even at higher prices, these individuals continued to have relatively high demand for alcohol). These results agree with existing studies that have discussed how increased alcohol misuse is associated with greater demand for alcohol (MacKillop et al., 2010).

Importantly, participants' demand for alcohol was associated with effort discounting. Q_0 was associated with lower effort discounting for both money and alcohol, suggesting that perhaps valuation of alcohol is related to willingness to complete effortful work. Moreover, alpha and effort discounting rates had a positive relationship. That is, as alpha decreased and demand became more inelastic, participants had lower effort discounting, meaning they were more willing to work to obtain money or alcohol.

The mediation analyses further explored the relationship between our demand parameters, alpha and Q_0, on alcohol use and effort discounting preferences for alcohol. Other studies have suggested differentiating the features within the demand curve to characterize demand preferences (Bickel et al., 2000, Hursh et al., 2005, Mackillop et al., 2009). More specifically, MacKillop et al. describes two main demand curve factors: 1) "amplitude" that describes the intensity of demand and 2) "persistence" that describes sensitivity to escalating prices (Mackillop et al., 2009). The factor of amplitude is primarily consisted of intensity of demand and to a lesser extent, O_{max}, and the persistence factor is primarily consisted of elasticity of demand, Pmax (maximum inelastic price), breakpoint (price at which consumption becomes zero), and to a limited extent O_{max} (maximum alcohol expenditure). Within this current study, these factors are represented by Q_0 and alpha, respectively. Q_0 had a mediating role between DSM score and effort discounting for alcohol, with significant

indirect effects (standardized indirect effect = −0.056, p=0.006), which was 37.8% of the total effect. Alpha, on the other hand, had an indirect effect that represented 12.8% (standardized indirect effect = −0.019, p=0.053) of the total effect, but was not significant. Overall, demand for alcohol appears to have a mediating role between DSM criteria for AUD and effort discounting for alcohol, with this effect being driven primarily by the "amplitude" of demand, as the indirect effect of Q_0 was approximately 3 times greater than that of alpha. This is consistent with existing literature that suggests that greater "amplitude" of the demand curve has a higher correlation to weekly alcohol use, heavy alcohol use, and problems related to alcohol use (Mackillop et al., 2009). A meta-analysis regarding the alcohol purchase task found similar findings with a weak relationship between price elasticity and drinking outcomes, while intensity or amplitude of demand better predicted AUD symptoms (Kiselica et al., 2016). While these results do not preclude the possibility that other factors may impact DSM score's effects on effort discounting preferences as well, it does support the notion that demand can help explain the relationship between higher alcohol use and effort discounting for alcohol. Together, these findings further support the results from Experiment 1 and help explain how demand for alcohol can impact participants' preferences among discounting options between waiting and working for the reward.

GENERAL DISCUSSION

Through these experiments, we ultimately sought to better understand and characterize effort discounting preferences among alcohol users. We replicated that individuals with greater AUD severity have increased delay discounting for both monetary and alcohol rewards, suggesting that they are less willing to wait for a reward (Petry, 2001, Field et al., 2007, MacKillop et al., 2011, Amlung et al., 2017). In contrast, individuals with greater AUD severity had lower effort discounting for alcohol, but not for money. This means that individuals with greater AUD severity were more willing to work to obtain alcohol.

These findings may be explained in part by higher demand, particularly initial demand with minimal cost, for alcohol in AUD populations. Other studies have shown a positive relationship between increased demand for substances and increased delay discounting (MacKillop et al., 2010), however less is known about the relationship between demand and effort discounting. In our effort discounting for alcohol task, individuals with higher Q_0's and lower alphas for alcohol had low effort discounting and therefore were more willing to work for alcohol.

This line of research also calls into question the relationship between delay and effort discounting. Some studies have suggested a positive association between these two processes; for example one study found a small, positive correlation between devaluation for delayed rewards and devaluation for rewards requiring higher degrees of effort (Mitchell, 1999). Although most studies have not refuted this relationship, other studies have described delay and effort discounting more as separate neurological processes that are related, but not equivalent (Ostaszewski et al., 2013). This idea is further explored in a separate study that found overlapping areas of the brain, such as the temporal and orbitofrontal cortices, with greater activity in tasks involving either delay or effort, while other parts of the brain were more uniquely activated by decisions involving delay or effort (Massar et al., 2015). This

suggests that overlapping, but non-identical areas of the brain are involved in decision making with delay or effort. Furthermore, external pressures may preferentially influence one process over the other, such as how one study showed that sleep deprivation increases effort discounting, but not delay discounting (Libedinsky et al., 2013). Further research remains to be conducted to better explain the neurologic mechanisms behind delay and effort discounting. From this study, although delay and effort discounting behaviors may vary depending on the situation for populations who abuse substances, both of these processes can contribute to negative decision making that can increase risk for drug abuse. As such, they remain important avenues for further research on addiction and behavioral choices.

A limitation of the present experiments was that the DSM recommends that a trained clinical professional evaluate AUD through an interview setting. However, to make the experiments suitable for mTurk, we assessed the DSM 5 criteria online through a self-report questionnaire. Another potential limitation was that participants may have had differences in interpreting alcohol as a theoretical reward, with some participants likely viewing the reward as something they would own while others viewing the alcohol as something they would have to drink right away. For example, some participants may have interpreted the alcoholic beverages as open containers that they would need to drink immediately, therefore a large amount of alcohol may not have necessarily been desirable. We tried to offset this by adding text that participants would theoretically receive the beverages “to use as [they] wish.” Despite the individual’s interpretation, the differences in relationships between AUD severity and ln(k) and task type demonstrate an important contribution to this field in helping to identify how an individual chooses to value his or her time and effort. A third potential limitation is that in the effort discounting tasks, greater effort was measured by a greater number of words that participants would theoretically be willing to type. Given that a larger amount of words to type would take more time to accomplish, the potential duration of this task may also contribute to our measurement of effort discounting. However, any added typing time is likely not significant compared to the durations in the delay discounting tasks. That is, although number of words typed was used to equate effort to delay in hours, we do not expect an individual to assume typing one word would take an hour. For example, an average speed typist (40 wpm) could type 2500 words in about an hour, an insignificant amount of time compared to 2500 hours (almost 15 weeks) in the delay task. Therefore, we do not expect this small increase in time to significantly impact the effort discounting. Moreover, if time was a significant contributing factor, we would not expect to see the increase in effort (i.e., decrease in effort discounting) in the individuals with greater AUD severity, especially given these individual’s delay discounting rates. Finally, the 5-trial minute discounting task used in these experiments uses a model for delay discounting that assumes a hyperbolic function, while other studies have suggested a parabolic model may explain variance in effort discounting data (Hartmann et al., 2013). Testing these theories further may require analyzing this type of data across different discounting models. Future expansions of work in this arena should also include exploration of how participant’s behaviors may change when they are actually asked to perform the work needed to obtain different rewards, instead of being purely hypothetical.

CONCLUSION

Together, these results suggest that individuals with greater alcohol use disorder severity are less willing to wait for a monetary reward but have a similar level of willingness as individuals without AUD to work for an equivalent amount of money. When the reward offered is alcohol, individuals meeting more DSM 5 criteria for AUD are still less willing to wait for the reward but were more willing than individuals with lower DSM scores to put in effort to obtain alcohol. Greater alcohol demand, particularly higher intensity of demand at low minimal cost, in individuals who misuse helps to account for some of these differences. Increased delay discounting across commodities and decreased effort discounting for alcohol among individuals with higher AUD severity may be a hazardous combination. This finding may be echoed across a number of addictions, such as how individuals who abuse opioids tend to have greater impulsivity, potentially engaging in risky behaviors such as sharing needles and taking extreme measures, such as visiting different providers, pharmacies, or even inflicting harm to themselves to obtain pain medication (Madden et al., 1997, Odum et al., 2000, O'Connell, 2014). Together, these results paint a picture of alcohol-dependent users as being more impulsive and more willing to work to obtain alcohol, contributing to our understanding of risky decision-making and negative outcomes among individuals who abuse substances. Ideally, further understanding of delay and effort discounting will help us better develop interventions that could address both of these factors and improve efforts in addiction recovery.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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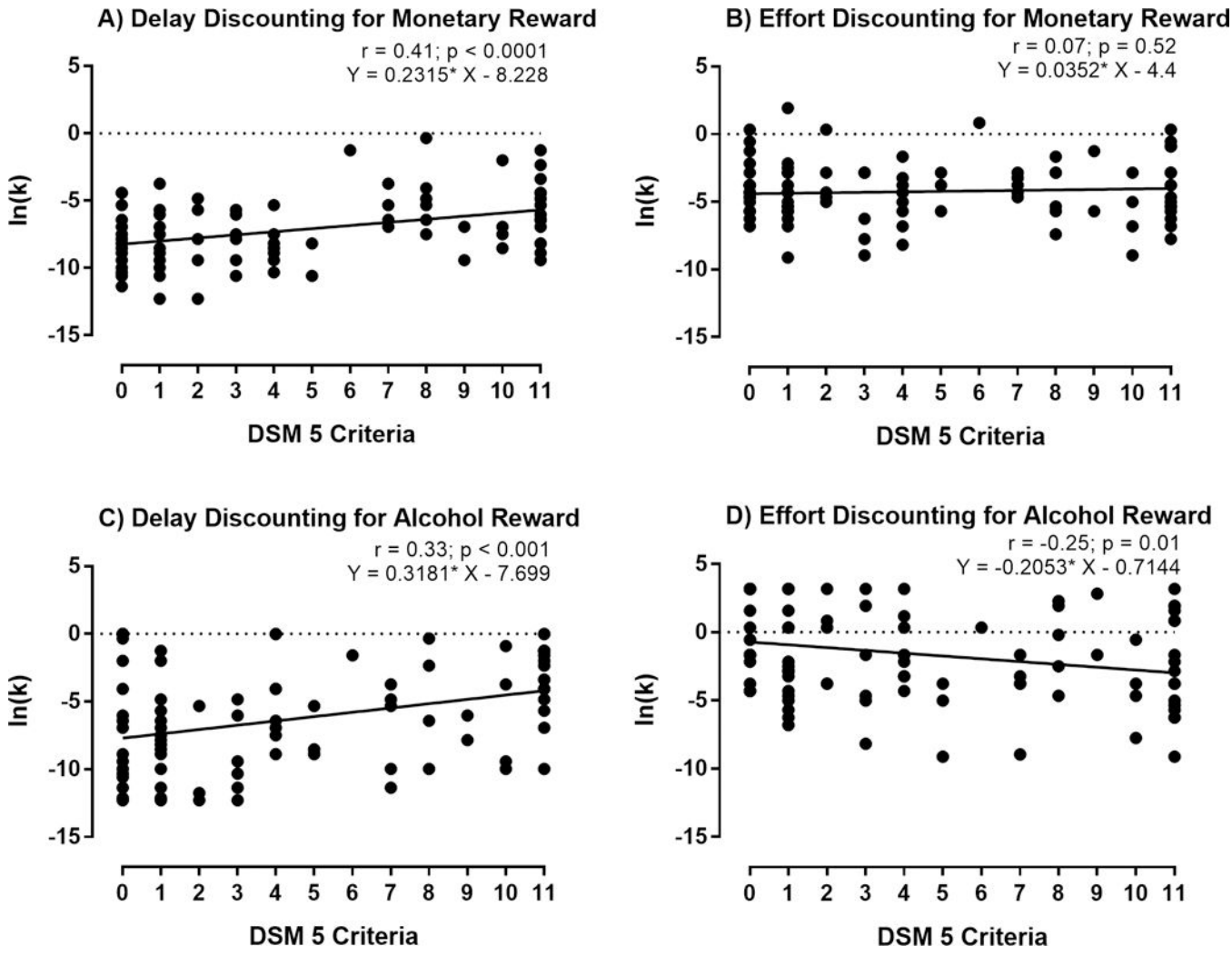

Figure 1. Experiment 1 - Relationship between discounting tasks ln(k)s and DSM 5 Criteria.

Panel A depicts the correlation between the Delay discounting for monetary reward task ln(*k*) and DSM 5 criteria as measured by participant self-report. The line depicts the linear regression for the reader. Panel B depicts Effort discounting for monetary rewards and DSM 5. Panel C depicts Delay discounting for alcohol rewards and DSM 5. Panel D depicts Effort discounting for alcohol reward task and DSM 5. The linear regression lines in each are represented for the reader. * denotes statistically significant correlation value with $p<0.05$.

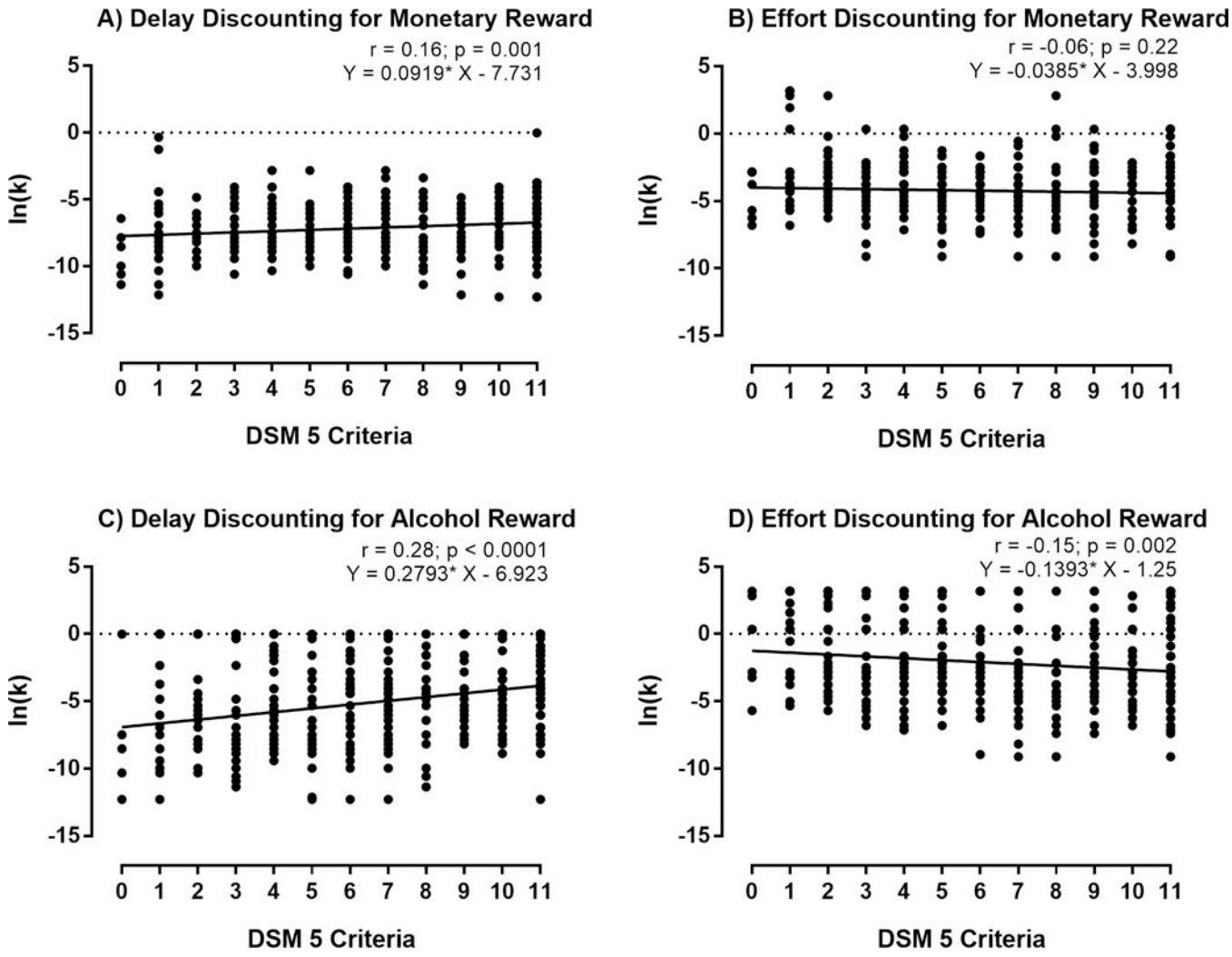

Figure 2. Experiment 2 - Relationship between discounting tasks ln(k)s and DSM 5 Criteria.

Panel A depicts the correlation between the Delay discounting for monetary reward task ln(k) and DSM 5 criteria as measured by participant self-report. The line depicts the linear regression for the reader. Panel B depicts Effort discounting for monetary rewards and DSM 5. Panel C depicts Delay discounting for alcohol rewards and DSM 5. Panel D depicts Effort discounting for alcohol reward task and DSM 5. The linear regression lines in each are represented for the reader. * denotes statistically significant correlation value with $p<0.05$.

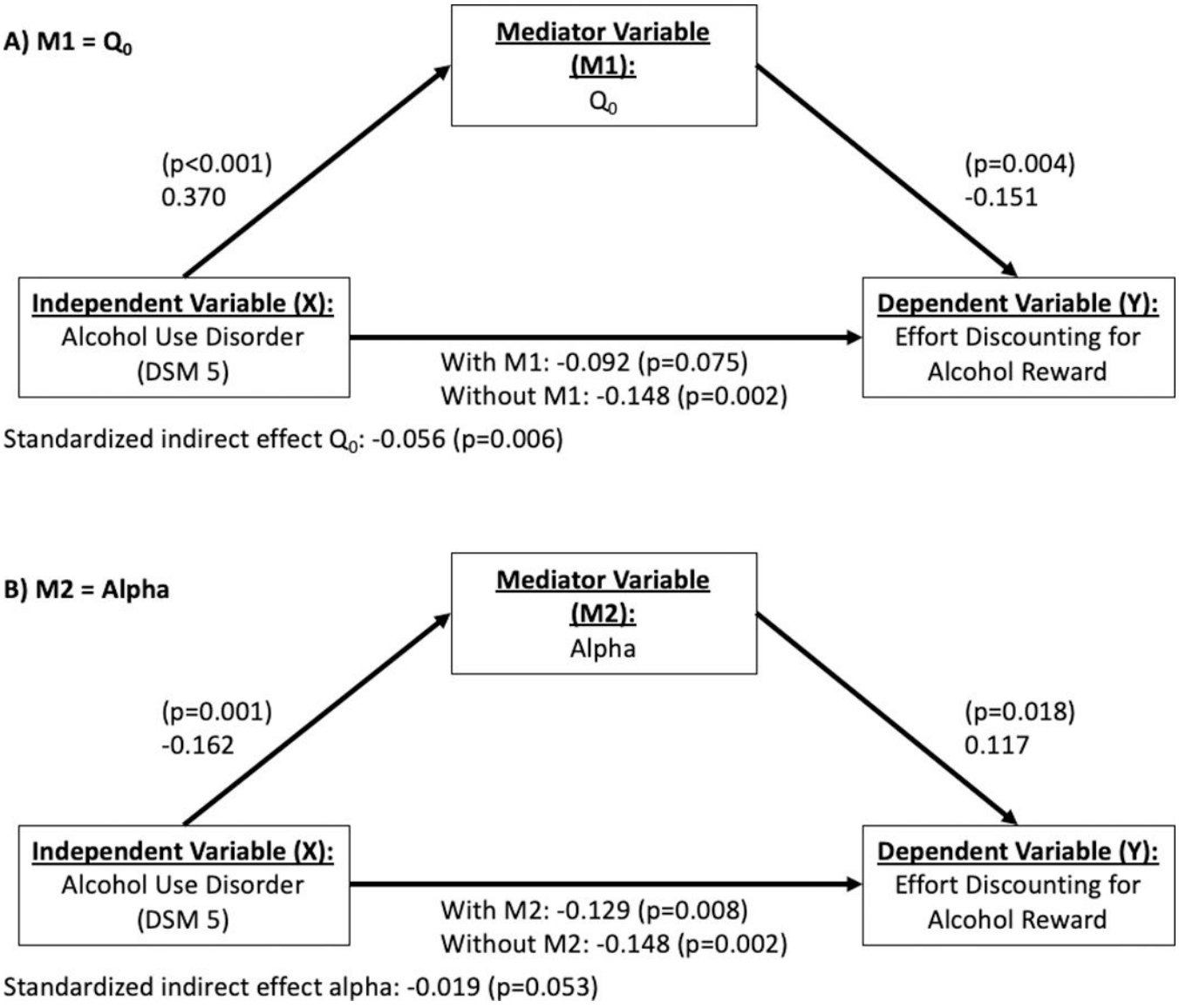

Figure 3. Mediation Analysis for the Relationship between Alcohol Use Disorder and Effort Discounting for Alcohol as Mediated by Demand.

Panel A depicts mediation analysis with Q_0 as a mediator. Panel B depicts mediation analysis with alpha as a mediator. Standardized β estimates of the linear regression between each set of variables are depicted along the arrows. Note panel A and panel B represent two separate mediation analyses and not one analysis with multiple mediators.

Table 1.

Experiment 1 - Correlation Matrix, Pearson r values

	$Time	$Effort	AlcTime	AlcEffort	DSM	Audit
$Time						
$Effort	0.18					
AlcTime	0.35***	0.16				
AlcEffort	0.07	0.28**	0.08			
DSM	0.41***	0.07	0.33**	−0.25*		
Audit	0.44***	0.12	0.40***	−0.27*	0.90***	

$Time: Delay discounting for monetary reward task; $Effort: Effort discounting for alcohol reward task; AlcTime: Delay discounting for alcohol reward task; AlcEffort: Effort discounting for alcohol reward task, DSM: DSM 5 criteria for alcohol use disorder; AUDIT: Alcohol use disorders identification test.

* p≤0.05

** p≤0.005

*** p≤0.0005

Table 2.

Experiment 2 - Correlation Matrix, Pearson r values

	$Time	**$Effort**	**AlcTime**	**AlcEffort**	**DSM**	**Audit**	**Q_0**	**Alpha**
$Time								
$Effort	0.23***							
AlcTime	0.25***	0.11*						
AlcEffort	0.06	0.37***	0.17**					
DSM	0.16**	−0.06	0.28***	−0.15**				
Audit	0.16**	−0.06	0.31***	−0.15**	0.82**			
Q_0	0.00	−0.14*	0.056	−0.19***	0.37***	0.43***		
Alpha	0.14**	0.22***	−0.11*	0.14**	−0.16**	−0.20***	−0.28***	

AlcTime: Delay discounting for alcohol reward task; AlcEffort: Effort discounting for alcohol reward task; Q_0: Initial consumption for a commodity at no cost to the subject; alpha: sensitivity in purchasing a commodity with increasing price.

* p≤0.05

** p≤0.005

*** p≤0.0005.