An experimental investigation into the effect of negative affect
on the behavioral economic demand for alcohol

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Abstract

Objective: Influential theoretical models hypothesize that alcohol use is an especially potent reinforcer when used as a strategy to cope with negative affect. Although the evidence for this idea in observational data is weak, some experimental evidence suggests that the behavioral economic demand for alcohol increases immediately following a negative emotional event. Because existing studies testing the effect of negative mood inductions on the demand for alcohol have several methodological limitations and do not take inter- and intraindividual variability into account, we developed an improved experimental design to increase our confidence in any potential within-person effect of negative mood inductions on alcohol demand as well as to test whether this effect exhibits systematic inter- and intraindividual variability. We hypothesize that people will show a higher demand for alcohol following negative compared to neutral mood inductions and that this effect is stronger in heavy compared to light drinkers as well as stronger on days characterized by higher coping motives and negative urgency.

Methods: 320 college students will complete the alcohol purchase task after being subjected to twelve mood inductions (six negative, six neutral) on twelve separate days.

Results:

Conclusions:

Keywords: Negative reinforcement, Alcohol use, Behavioral economic demand, Mood induction,

Registered Report

Public Significance Statement

While the evidence for negative reinforcement of alcohol use in everyday life is weak, it remains plausible that the momentary reinforcing value of alcohol increases following negative emotional experiences. This experiment will rigorously test this idea outside of the laboratory, which will improve our understanding of the drinking-to-cope pathway to alcohol use.

Introduction

Multiple influential models hypothesize that alcohol use is a negatively reinforcing behavior (e.g., Baker et al., 2004; Conger, 1956; Cooper et al., 1995). People are assumed to become increasingly more likely to consume alcohol when they experience negative and aversive emotions to ‘self-medicate’ (Khantzian, 1990) or ‘reduce tension’ (Greeley & Oei, 1999) as they learn to associate alcohol with its anxiolytic and mood-enhancing effects over repeated exposures (so-called stimulus-response or reinforcement learning; Dayan & Daw, 2008; Niv, 2009).

Despite the popularity of these models, a large body of observational ecological momentary assessment data indicates that people do not consume more alcohol on days characterized by higher negative affect. Although some early studies provided preliminary support for the expected daily association between negative affect and alcohol use (e.g., Armeli et al., 2000; Park et al., 2004; Simons et al., 2005), further investigations as well as a recent meta-analysis of data from over 12,000 participants did not replicate this effect across a range of operationalizations of affect, study populations, as well as study-specific and individual characteristics (Dora et al., n.d.; Ehrenberg et al., 2016; Gautreau et al., 2015; O’Donnell et al., 2019).

This null association between daily affect and alcohol use is at odds with the relatively robust evidence for negative affective reinforcement of other dysregulated behaviors, such as binge eating (Haedt-Matt & Keel, 2011; Macht & Simons, 2011) and smoking (Akbari et al., 2020; Bold et al., 2016; Gehricke et al., 2007). One crucial difference is that eating and smoking are commonly engaged in throughout the day and week, whereas people are much more likely to drink alcohol in the evening, on weekends, and while surrounded by other people (Acuff et al.,

2021; Arfken, 1988). These situational constraints might mean that even *if* alcohol is sometimes a negatively reinforced behavior, it most typically occurs in positively reinforcing social situations. Moreover, people may experience many instances of negative affect when they might want to drink but cannot (e.g., during the day while at work, caring for a child, or driving). A better understanding of the drinking-to-cope pathway to alcohol use would be invaluable to the prevention and treatment of problematic alcohol behaviors to better specify for whom and when drinking-to-cope is relevant as an intervention target.

Negative reinforcement value of alcohol

Although alcohol use is situationally constrained, if alcohol is a negatively reinforced behavior, we should expect the momentary reinforcing value of alcohol (i.e., the desire to drink or to allocate resources in order to obtain alcohol) to increase following the experience of negative affect. However, the reinforcing value of alcohol has not been directly measured in observational studies focused on the experience of negative affect. Indeed, some evidence suggesting that alcohol might have reinforcing value in the context of negative affect comes from laboratory research using the alcohol purchase task (Murphy & Mackillop, 2006). In this task, participants indicate the amount of alcohol they would consume (either in a hypothetical scenario or in the moment) along a range of escalating prices per alcoholic drink. Responses on this task have been shown to correlate with real-world alcohol consumption, alcohol problems, and treatment outcomes (Murphy et al., 2015; Murphy & Mackillop, 2006). That is, higher demand for alcohol as indicated via the alcohol purchase task has been shown to correlate with heavy drinking across a variety of populations and reduction in demand have been shown to correlate with reductions in drinking intensity in the context of a brief alcohol intervention.

Several indicators of the demand for alcohol can be derived from the alcohol purchase task data, such as the number of drinks one would consume when drinks are free (intensity), the price at which one would no longer purchase any alcohol (breakpoint), the maximum amount of money one would spend on alcoholic drinks in that moment ($O_{\max}$), the price corresponding to this maximum expenditure ($P_{\max}$), and the slope of the demand curve as price increases (elasticity). Three studies indicated that intensity and $O_{\max}$ might be the demand index exhibiting the strongest correlation with real-world alcohol use and alcohol problems (Martinez-Loredo et al., 2020; Murphy et al., 2015; Murphy & Mackillop, 2006).

In two within-subjects laboratory experiments (Amlung & Mackillop, 2014; Owens et al., 2015), several indicators of alcohol demand, including $O_{\max}$, were elevated following a negative mood induction compared to a neutral mood treatment. Additionally, an experiment employing a between-subjects design found that participants who were subjected to a negative mood induction were more likely to choose an alcoholic drink over a monetary reward compared to participants who were subjected to a neutral mood treatment (Rousseau et al., 2011). One interpretation of these findings is that the reinforcing value of alcohol increases as negative affect increases, supporting negative reinforcement models of alcohol use.

These earlier experimental studies can only provide limited support for the negative reinforcement of alcohol demand due to several methodological limitations. A between-subjects design, as employed by Rousseau and colleagues (2011), does not directly test the hypothesis that a person will value alcohol more following an event inducing negative affect compared to a neutral event. Amlung and Mackillop (2014) did not counter-balance the order of the negative and neutral mood induction, making it impossible to rule out order effects. None of the studies tested the effect of mood inductions on alcohol demand across multiple days outside of the

laboratory, limiting their findings' generalizability to real world situations. In summary, the three reviewed studies testing effects of negative mood inductions on the subjective value of alcohol (Amlung & Mackillop, 2014; Owens et al., 2015; Rousseau et al., 2011), while reporting significant effects of mood manipulations on alcohol demand, do not provide strong evidence for the negatively reinforcing value of alcohol demand.

The present study

The present study aims to build on these earlier experiments to achieve two goals. First, we will perform a more rigorous test of the hypothesis that people have a higher demand for alcohol following a negative emotional event compared to a neutral emotional event. In order to achieve this aim, we will repeat the alcohol purchase task assessment a total of twelve times on twelve separate days. We will use three different mood induction techniques which have been shown to successfully induce negative affect online (Marcusson-Clavertz et al., 2019; Verheyen & Goritz, 2009); the presentation of an emotion-eliciting text, emotion-eliciting photographs, as well as the Velten mood induction (in which participants are instructed to try to feel the mood described in several self-referent statements). We will expose participants to two variations of each of these six mood inductions (three negative, three neutral) in randomized order, for a total of twelve inductions. By inducing negative and neutral moods on separate days, we reduce the risk of unwanted order effects in our data (i.e., the tendency of participants' responses on the alcohol purchase task to be influenced by earlier responses as well as the unequal influence of the mood inductions on subsequent responses). Thus, we are going to manipulate mood and assess alcohol demand repeatedly in people's natural environment while collecting a much larger sample than previous studies, which will increase the group-level precision of the estimates of interest, and thus increase our confidence in the conclusions. Compared to investigations

performed solely in the lab, this will also increase the ecological validity of our findings, which is critical given the discrepant findings in real-world observational and lab-based experimental findings in this literature (Bresin et al., 2018; Dora et al., n.d.). A previous study has established the validity of repeatedly assessing alcohol demand in everyday life (Merrill & Aston, 2020).

Second, we will test three moderators of the association between negative affect and alcohol demand; individual differences in alcohol consumption and momentary coping motives and negative urgency. Affect regulation models (Baker et al., 2004; Koob & Le Moal, 2008) do not assume that alcohol is reinforcing for every single individual or in every single moment. It may be that increases in alcohol demand following a negative emotional event are limited to people who have a strong tendency to consume alcohol in general (which would indicate that the drinking response to negative affect is learned via reinforcement), or whether people who have not had much exposure to alcohol also crave a drink when feeling down (e.g., via expectations surrounding the consumption of alcohol; Drobles et al., 2009).

Emerging evidence suggests that coping motives on the state-level might explain when people attempt to cope with their negative affect via alcohol (versus not; Stevenson et al., 2019). This may suggest that people are particularly susceptible to negative reinforcement on days where they formulate a conscious motivation to cope with their negative affect via drinking. Finally, some EMA data suggest that negative urgency, which is a personality factor studied on the trait- and state level characterized by an increased tendency to act impulsively in the face of negative affect, might moderate the negative affect-alcohol use association (Bold et al., 2017), though this effect did not replicate in two college samples (Dora et al., 2022). Thus, it may also be that people are particularly susceptible to negative reinforcement on days on which they report a tendency to behave impulsively when experiencing negative emotions.

Hypotheses

In summary, in this paper we aim to understand whether the behavioral economic demand of alcohol increases on days characterized by a negative emotional event (compared to a neutral emotional event), and whether this increase implies support for affect-regulation models of alcohol use. We derive four hypotheses from the negative reinforcement idea. First, we hypothesize that people will report higher alcohol demand ($O_{\max}$) following negative mood inductions compared to neutral mood inductions. In our confirmatory analyses, we will focus on $O_{\max}$ compared to alternative demand indices since we believe it most strongly reflects the momentary subjective value of alcohol¹. Second, we hypothesize that individual differences in self-reported alcohol consumption will moderate the effect of our mood manipulations on alcohol demand, so that the effect is stronger for people reporting higher alcohol use. Third, we hypothesize that daily coping motives moderate the effect of our mood manipulations on alcohol demand, so that the effect is stronger on days people report higher coping motives. Fourth, we hypothesize that daily negative urgency moderates the effect of our mood manipulations on alcohol demand, so that the effect is stronger on days people report higher negative urgency.

On twelve consecutive days, participants will (a) report their momentary affect, daily coping motives, and negative urgency, (b) be subjected to one of twelve mood inductions (six negative, six neutral; randomized on the day-level), (c) complete the alcohol purchase task, and (d) report momentary affect once more.

Method

Ethics information

¹ Intensity, breakpoint, and elasticity will be predicted in exploratory analyses.

This research complies with the University of Washington's ethics regulations.

Participating college students will provide informed consent and will receive course credits for participation. In order to incentivize a high completion rate, participants will receive more credits the more daily assessments they complete.

Procedure and design

The proposed study employs a repeated-measures within-subjects (negative vs neutral mood inductions) design. After signing up for the study and providing informed consent, participants will first complete our baseline assessment. They will then receive an email and text message with a survey link every day at 4pm for twelve consecutive days (with one reminder sent at 6:30pm), and will be instructed to respond to the survey between 4pm and 9pm but *before* they consume any alcohol on that day. Each day, participants will first report on their momentary affect, daily coping motives, and daily negative urgency. Next, they will be subjected to one of the twelve mood inductions (6 negative mood inductions, 6 neutral mood inductions), which are described below. Afterwards, they will complete the daily alcohol purchase task, which is described below, and report on their momentary affect once more. Each daily assessment will take approximately twenty minutes to complete. After the twelfth day of participation, participants will be debriefed and will receive their compensation. The sequence of the daily assessments is visualized in Figure 1.

Figure 1. Sequence of events in daily assessment. (A) Self-report of affect, motives, and urgency. (B) Exposure to one mood induction; randomized between days. (C) Alcohol purchase task. (D) Self-report of affect.

Baseline assessment

Participants will report demographic information, receive instructions regarding the size of a standard alcoholic drink, self-report on their typical alcohol consumption levels (via the 3-item alcohol consumption subscale of the Alcohol Use Disorder Identification Test; Allen et al., 1997), and will fill in baseline measures of the constructs assessed on the day-level (affect, drinking motives, urgency, and alcohol demand). The baseline survey will take approximately twenty minutes to complete.

Daily assessment

Participants will be asked to fill in the daily assessment on their personal computer, laptop, or smartphone by clicking on the link provided to them via email and text message. We will instruct them to make sure that they are in a quiet place by themselves and with no distractions. They will be asked to fill in the daily assessment only if they did not consume alcohol on that day. At the start of the assessment, for planned sensitivity analyses, participants will be asked to indicate the amount of alcoholic drinks they consumed the previous day. For exploratory purposes, participants will be asked to self-report to what extent they crave a drink in that moment after completing the alcohol purchase task.

Negative affect. Participants will fill in the ten-item negative affect subscale of the PANAS ($\alpha = 0.85$; Watson et al., 1988). They will rate the extent to which they currently feel different negative emotions (e.g., *distressed, guilty, upset*) on a 100-point visual analogue scale (scale anchor 0 = “not at all” – 100 = “very much”). We will average these ten items to compute a momentary negative affect score. For exploratory purposes, participants will also fill in a subset of five items (*determined, enthusiastic, excited, inspired, interested*) of the positive affect subscale of the PANAS.

Coping motives. Participants will fill in the five-item coping motives subscale of the Drinking Motives Questionnaire ($\alpha = 0.86$; Cooper, 1994), which we adapt to reflect daily rather than dispositional coping motives (Stevenson et al., 2019). Participants will rate the extent to which they are motivated to drink-to-cope with negative emotions on the day of assessment (e.g., “*Today, I might drink in order to forget about my problems.*”) on a 100-point visual analogue scale (scale anchor 0 = “not at all” – 100 = “very much”). We will average these five items to compute a daily coping motives score. For exploratory purposes, participants will also fill in a

subset of two items (*“Today, I might drink in order to get high.”*, *“Today, I might drink because it is fun.”*) of the enhancement motives subscale of the DMQ.

Negative urgency. Participants will fill in the four-item negative urgency subscale of the Short UPPS-P ($\alpha = 0.78$; Cyders et al., 2014), which we adapt to reflect daily rather than dispositional negative urgency. Participants will rate the extent to which they responded impulsively to negative emotions on the day of assessment (e.g., *“Today I felt rejected and said things that I now regret.”*) on a 100-point visual analogue scale (scale anchor 0 = “not at all” – 100 = “very much”). We will average these four items to compute a daily negative urgency score. For exploratory purposes, participants will also fill in a subset of two items (*“Today I was in a great mood and got into a situation that caused me problems.”*, *“Today I acted without thinking when I was really excited.”*) of the positive urgency subscale of the SUPPS-P.

Mood inductions. Mood inductions will be randomized on the day-level, with each of the twelve mood induction variations being presented once to each participant. (1) Emotion-eliciting text: On four random days, participants will read a short text. On two days, they will read a text that has been shown to induce negative affect in previous work (c.f. Verheyen & Goritz, 2009). These texts cover a first-person narrative of a young woman whose father died after suffering from Alzheimer’s disease and the unpleasant description of two death penalty executions in the electric chair. On the other two days, they will read texts which are neutral in their affective valence, namely a description of human’s evolved picture of the universe throughout history and a description of Darwin’s theory of evolution. Participants will be instructed to become aware of the emotions they feel while reading the text. (2): Emotion-eliciting photographs: On four random days, participants will look at 10 photographs each. On two days, they will look at a set of 10 photographs from the International Affective Picture Set with a mood valence rating of <

2.5 and an arousal rating of < 6 (Lang et al., 2008). On the other two days, they will look at a set of 10 photographs from the IAPS with a mood valence rating between 4.5 and 5.5 and an arousal rating of $< 6^2$. No photograph will be used twice. Participants will be instructed to become aware of the emotions they feel while looking at the picture. (3): Velten procedure: On four random days, participants will read through 10 statements. On two days, these will be negative self-referent statements; on the other two days, they will be neutral self-referent statements (c.f. Marcusson-Clavertz et al., 2019). Participants will be asked to think about each statement and to feel the mood suggested by them (Velten, 1968).

Alcohol purchase task. After studying a reminder regarding the size of a standard alcoholic drink, participants will complete an APT based on previous work (Mackillop et al., 2010; Merrill & Aston, 2020). Participants will report how many alcoholic drinks (min = 0; max = 20) they would consume *in that moment* at 11 different prices ranging from \$0.00 to \$10.00 per drink. They will be instructed to assume that they do not have alternative opportunities to consume alcohol on that day, and that they cannot stockpile drinks to be consumed at a later date.

Sampling plan

We conducted a set of simulations ($N = 1,000$) to calculate required sample size to limit the width of the 95% credible interval (accuracy in parameter estimation; Maxwell et al., 2008) for the experimental effect of treatment on $O_{\max}$ to \$10. For these simulations, we assumed an average response rate of 83%, an average $O_{\max}$ of \$15 with a mean difference of \$5 between negative and neutral mood inductions, a \$5 standard deviation on the random intercept per

² An overview over the IAPS picture numbers used in this study can be found on the Open Science Framework project of this article <https://osf.io/fks3j>.

participant, a \$2.50 standard deviation on the random intercept per induction, as well as a residual standard error of \$1. We made these assumptions based on alcohol purchase task data that we obtained from another research group for this purpose. These simulations revealed that we would limit the width of the 95% credible interval to less than 10\$ in 91% of simulations with $N = 80$ participants. In order to conservatively account for the assumptions made in these simulations as well as to make sure we are adequately powered for our interaction tests, we will quadruple this sample size for a total of $N = 320$ ³.

320 college students will participate in exchange for partial course credit. The sample will be recruited via the University of Washington's pool of undergraduate students. Participants will have to be between 18 and 24 years of age. Participants who report to abstain from alcohol at baseline will be excluded from the study. Data from days on which participants report to have consumed alcohol prior to the daily assessment (since waking up) will be excluded from all analyses.

Analysis plan

We will conduct all of our analyses in R (R Core Team, 2021). We will test our hypotheses using a Bayesian mixed-effects modeling approach using the `brm` function (*brms* package; Bürkner, 2017). In all analyses, the day will be the unit of analysis. $O_{\max}$ will be directly derived from the APT data and equals the maximum alcohol expenditure at any price level. In line with previous work (Amlung & Mackillop, 2014), $O_{\max}$ values with a z-score ± 3.99 will be winsorized so that the outlying value will be 0.001 greater than the next highest non-

³ The power simulation script outlining all assumptions made can be found on the Open Science Framework project of this article <https://osf.io/fks3j>.

outlying value⁴. The manipulation will be treatment-coded (neutral = 0; negative = 1).

Continuous predictors will be standardized on a sample level (alcohol consumption) and on an individual participant-level (motives, urgency) so that they have a mean of 0 and a standard deviation of 1.

Random effects structure. We will aim for a ‘maximal’ random effects structure (Barr et al., 2013). Accordingly, we will fit a random intercept nested in participants to account for differences in alcohol demand between participants. We will fit random slopes for our predictors (except for typical alcohol consumption, as that will be assessed between-participants) nested in participants to account for variability in the effect of the predictors on alcohol demand between participants. Additionally, we will fit a second random intercept nested in mood induction to account for any additional variance in alcohol demand caused by the specific mood inductions used in our study, resulting in the following general R syntax: $O_{\max} \sim 1 + \text{predictors} + (1 + \text{predictors} \mid \text{participant}) + (1 \mid \text{induction})$.

Priors and inferences. We will use weakly informative priors for our fixed effects of interest ($\text{prior}(\text{normal}(0, 10), \text{class} = \text{b})$, $\text{prior}(\text{student_t}(3, 1, 5), \text{class} = \text{sigma})$). We will report the posterior probability of a range of effect sizes, interpreting differences in $O_{\max}$ of 5\$ or larger following the negative vs neutral mood inductions as meaningful effects. Thus, we will compute and report the posterior probability that the effect is at least as large as our smallest effect size of interest alongside a Bayes Factor using the Savage-Dickey density ratio (Wagenmakers et al., 2010) in favor of an effect of treatment on $O_{\max}$ of 5\$.

⁴ The processing script can be found on the Open Science Framework project of this article <https://osf.io/fks3j>.

To account for potential carry-over effects of alcohol consumed the previous evening, we will perform two sensitivity analyses, one in which we will exclude data from days on which participants endorsed alcohol use on the previous evening and one in which we will control for the number of alcoholic drinks consumed. In exploratory analyses, we will predict further demand indices derived from the APT data (breakpoint, intensity, elasticity) as well as self-reported craving, and will replace negative affect, coping motives, and negative urgency with positive affect, enhancement motives, and positive urgency respectively. We will report these exploratory analyses in the final manuscript or the supplementary materials. For each model, we will run four Markov chain Monte Carlo (MCMC) chains with 4,000 iterations. We will inspect model fit using the Rhat statistic, effective sample sizes, trace plots, and posterior predictive checks.

Data availability statement

All data will be publicly shared on the Open Science Framework project of this article <https://osf.io/fks3j/>.

Code availability statement

All code will be publicly shared on the Open Science Framework project of this article <https://osf.io/fks3j/>.

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