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An Experimental Investigation Into the Effect of Negative Affect on the Behavioral Economic Demand for Alcohol

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Objective: It is hypothesized that alcohol use is reinforcing when used as a strategy to cope with negative affect. Although the evidence for this hypothesis in observational data is weak, some experimental evidence suggests that the behavioral economic demand for alcohol increases immediately following a negative emotional event. We hypothesized that people show a higher demand for alcohol following negative (vs. neutral) mood inductions and that this effect is stronger in people who report heavier drinking compared to people who report lighter drinking as well as stronger on days characterized by higher coping motives and negative urgency. ***Method:*** 309 college students who reported recent alcohol consumption ($M_{AUDIT} = 6.86$) completed the alcohol purchase task after being subjected to 12 mood inductions (six negative, six neutral, order randomized) on 12 separate days. ***Results:*** In our preregistered analyses, we found no evidence that the behavioral economic demand for alcohol was elevated following negative mood inductions. The mood inductions in our study were not as strong as has been reported in previous research, weakening the preregistered inferences. In exploratory analyses performed on a subset of the data in which the mood inductions worked as intended, demand was higher following negative mood inductions. ***Conclusions:*** The results of this study are not conclusive. In light of previous research, we consider these data to slightly increase our confidence that demand for alcohol is increased immediately following a negative emotional event.

Public Health Significance Statement
This experiment tested in a nonclinical sample of college students whether the momentary reinforcing value of alcohol increases following negative emotional experiences. The results were not conclusive as we learned that repeatedly manipulating people's mood outside of the laboratory does not work as well as doing it once under controlled conditions. We can conclude that when the mood inductions worked as intended, the demand for alcohol increased when people were in a negative affective state.

Keywords: negative reinforcement, alcohol use, behavioral economic demand, mood induction, registered report

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Multiple influential models hypothesize that alcohol use is a negatively reinforcing behavior (e.g., Baker et al., 2004; Conger, 1956; M. L. 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, Piccirillo, et al., 2023; 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 (APT; 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 APT has been shown to correlate with heavy drinking across a variety of populations, and reduction in demand has been shown to correlate with reductions in drinking intensity in the context of a brief alcohol intervention (Gex et al., 2022; Martínez-Loredo et al., 2021).

Several indicators of the demand for alcohol can be derived from the APT 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 indices exhibiting the strongest correlation with real-world alcohol use and alcohol problems (Martínez-Loredo et al., 2021; 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 induction. 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 induction (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 et al. (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 counterbalance 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 aim to 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 repeat the APT assessment a total of 12 times on 12 separate days. We 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 expose participants to two variations of each of these six mood inductions (three negative, three neutral) in randomized order, for a total of 12 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 APT to be influenced by earlier responses as well as the unequal influence of the mood inductions on subsequent responses). Thus, we manipulate mood and assess alcohol demand repeatedly in people's natural environment while collecting a much larger sample than previous studies. Compared to investigations performed solely in the lab, this increases 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, Piccirillo, et al., 2023). A previous study has established the validity of repeatedly assessing alcohol demand in everyday life (Merrill & Aston, 2020).

Second, we 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; Drobes 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 (vs. 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 ecological momentary assessment data suggest that negative urgency, which is a personality factor studied on the trait and state levels 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 article, 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 report higher alcohol demand (O_{max}) following negative mood inductions compared to neutral mood inductions. In our confirmatory analyses, we focus on O_{max} compared to alternative demand indices since we believe it most strongly reflects the momentary subjective value of alcohol.[1] 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 12 consecutive days, participants (a) reported their momentary affect, daily coping motives, and negative urgency; (b) were subjected to one of 12 mood inductions (six negative, six neutral; randomized on the day level); (c) completed the APT; and (d) reported momentary affect once more.

Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in this study.

Ethics Information

This research was approved by the University of Washington's institutional review board under ID STUDY00014323. Participating college students provided informed consent and received course credits for participation. In order to incentivize a high completion rate, participants received more credits the more daily assessments they completed.

Sample Size Rationale

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 mood induction 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 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 APT 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 were adequately powered for our interaction tests, we quadrupled this sample size for a total of $N = 320$.[2]

Participants, Procedure, and Design

320 college students participated in exchange for partial course credit. The sample was recruited via the University of Washington's pool of undergraduate students. Participants had to be between 18 and 24 years of age. Participants who reported abstaining from alcohol at baseline were excluded from the study. Data from days on which participants reported to have consumed alcohol prior to the daily assessment (since waking up) were excluded from all analyses. Eleven participants did not complete at least one daily assessment in which a negative and one in which a neutral mood induction took place, leaving us with a final sample size of 309 participants ($M_{age} = 19.51$, $SD_{age} = 1.37$; $M_{AUDIT} = 6.86$, $SD_{AUDIT} = 4.99$). At baseline,

[1] Intensity and breakpoint were predicted in exploratory analyses.

[2] The power simulation script outlining all assumptions made can be found on the Open Science Framework project of this article at https://osf.io/fks3j.

participants on average reported to drink 2–4 times per month and to have six or more drinks on one occasion about once a month. An overview of demographics can be found in Table 1.

The proposed study employed a repeated-measures within-subjects (negative vs. neutral mood inductions) design. After signing up for the study and providing informed consent, participants first completed our baseline assessment. During the baseline assessment, participants received an overview of the daily procedures on the following days and instructions on how and when to complete the daily assessments. They then received an email and text message with a survey link every day at 4 p.m. for 12 consecutive days (with one reminder sent at 6:30 p.m.) and were instructed to respond to the survey between 4 p.m. and 9 p.m. but *before* they consume any alcohol on that day. Each day, participants first reported on their momentary affect, daily coping motives, and daily negative urgency. Next, they were subjected to one of the 12 mood inductions (six negative mood inductions, six neutral mood inductions), which are described below. Afterward, they completed the daily APT, which is described below, and reported on their momentary affect once more. Each daily assessment took approximately 20 min to complete. After the 12th day of participation, participants were debriefed and received their compensation. We used Inclivio (https://inclivio.com) to conduct the within-person randomization of mood inductions and send the daily assessments and reminders to participants via text message and email.

Baseline Assessment

Participants reported demographic information, received instructions regarding the size of a standard alcoholic drink, self-reported on their typical alcohol consumption levels (via the three-item Alcohol Consumption subscale of the Alcohol Use Disorder Identification Test; Allen et al., 1997), and filled in baseline measures of the constructs assessed on the day level (affect, drinking motives, urgency, and alcohol demand). The baseline survey took approximately 20 min to complete.

Table 1
Overview of Demographics

Demographics	*N*
Sex	
Female	203
Male	105
Gender	
Female	196
Male	105
Nonbinary	6
Genderqueer	1
Transgender	1
Race/ethnicity	
Asian	146
White	118
Hispanic	21
Black/African American	5
Other	16

Note. Participants were allowed to skip these questions or select multiple options when asked about gender and race/ethnicity, which is why responses do not need to sum up to 309.

Daily Assessment

Participants were 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 instructed them to make sure that they are in a quiet place by themselves and with no distractions. They were 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 were asked to indicate the number of alcoholic drinks they consumed the previous day. For exploratory purposes, participants were asked to self-report to what extent they craved a drink in that moment after completing the APT.

Negative Affect

Participants filled in the 10-item Negative Affect subscale of the Positive and Negative Affect Schedule ($\alpha = .85$; Watson et al., 1988). They rated the extent to which they currently feel different negative emotions (e.g., distressed, guilty, upset) on a 100-point Visual Analog Scale (scale anchor: 0 = *not at all*–100 = *very much*).

Coping Motives

Participants filled in the five-item Coping Motives subscale of the Drinking Motives Questionnaire ($\alpha = .86$; M. Cooper, 1994), which we adapted to reflect daily rather than dispositional coping motives (Stevenson et al., 2019). Participants rated the extent to which they were 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 Analog Scale (scale anchor: 0 = *not at all*–100 = *very much*). We averaged these five items to compute a daily coping motives score.

Negative Urgency

Participants filled in the four-item Negative Urgency subscale of the Short UPPS-P ($\alpha = .78$; Cyders et al., 2014), which we adapted to reflect daily rather than dispositional negative urgency. Participants rated 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 Analog Scale (scale anchor: 0 = *not at all*–100 = *very much*). We averaged these four items to compute a daily negative urgency score.

Mood Inductions

Mood inductions were randomized on the day level, with each of the 12 mood induction variations being presented once to each participant. (a) Emotion-eliciting text: On 4 random days, participants read a short text. On 2 days, they read a text that has been shown to induce negative affect in previous work (cf. 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 2 days, they 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 were instructed to become aware of the emotions they feel while reading the text. (b): Emotion-eliciting

photographs: On 4 random days, participants looked at 10 photographs each. On 2 days, they looked at a set of 10 photographs from the international affective picture set (IAPS) with a mood valence rating of <2.5 and an arousal rating of <6 (Lang et al., 2008). On the other 2 days, they looked 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.[3] No photograph was used twice. Participants were instructed to become aware of the emotions they feel while looking at the picture. (c): Velten procedure: On 4 random days, participants read through 10 statements. On 2 days, these were negative self-referent statements; on the other 2 days, they were neutral self-referent statements (cf. Marcusson-Clavertz et al., 2019). Participants were asked to think about each statement and to feel the mood suggested by them (Velten, 1968).

APT

After studying a reminder regarding the size of a standard alcoholic drink, participants completed an APT based on previous work (Mackillop et al., 2010; Merrill & Aston, 2020). Participants reported 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 were 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 later. For exploratory purposes, participants also reported alcohol craving via one item on a 100-point Visual Analog Scale (scale anchor: 0 = *not at all*–100 = *very much*).

Analysis Plan

We conducted all of our analyses in R (Version 4.3.1; R Core Team, 2021). We tested our hypotheses using a Bayesian mixed-effects modeling approach using the brm function (*brms* package; Bürkner, 2017). In all analyses, the day was the unit of analysis. O_{max} was directly observed 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 were winsorized so that the outlying value was 0.001 greater than the next highest nonoutlying value.[4] The manipulation was treatment-coded (neutral = 0; negative = 1). Continuous predictors were 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 *SD* of 1.

Random Effects Structure

We aimed for a "maximal" random effects structure (Barr et al., 2013). Accordingly, we fit a random intercept nested in participants to account for differences in alcohol demand between participants. We 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 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} ~ 1 + predictors + (1 + predictors|participant) + (1| induction).

Priors and Inferences

We planned to use the following weakly informative priors for our fixed effects of interest (prior(normal(0, 10), class = *b*), prior(student_*t*(3, 1, 5), class = sigma)). These priors were preregistered based on the assumption that O_{max} would be normally distributed, as it typically is in cross-sectional research. What we failed to consider is that in cross-sectional research, participants are asked to imagine a typical drinking situation when completing the APT, whereas in our study they were asked to complete the APT based on how they felt in that moment. Unsurprisingly (in hindsight), this resulted in many O_{max} values of 0 (e.g., on any given Monday evening a participant is much less likely to be willing to consume alcohol than when imagining a Friday night out with their friends). To appropriately model these data, we thus post hoc decided to analyze our data with a hurdle model, in which we separately predict O_{max} values of 0 and then predict values greater than 0. For this reason, we adapted our weakly informative priors to be (prior(normal(0, 5), class = *b*), prior(normal(0, 0.5), class = *b*, dpar = hu), prior(student_*t*(3, 1, 5), class = *SD*)). We report the posterior probability of a range of effect sizes, interpreting differences in O_{max} of 5$ or larger following the negative versus neutral mood inductions as meaningful effects.[5] 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 (BF) in favor of an effect of mood induction on O_{max}. Interaction models contained both main effects and the product term. In case of a product term that excludes 0, we planned to calculate conditional effects of the mood induction at several values of the moderator and to interpret these effect sizes similar to main effects.

To account for potential carryover effects of alcohol consumed the previous evening, we performed two sensitivity analyses, one in which we excluded data from days on which participants endorsed alcohol use on the previous evening and one in which we controlled for the number of alcoholic drinks consumed. In exploratory analyses, we predicted further demand indices derived from the APT data (breakpoint, intensity) as well as self-reported craving. For each model, we ran four Markov chain Monte Carlo chains with 4,000 iterations. We inspected model fit using the Rhat statistic, effective sample sizes, trace plots, and posterior predictive checks.

Results

Descriptive Statistics

Participants responded to 10.76 (89.67%) daily assessments on average. On 225 days (6.8%), participants reported to have already consumed alcohol at the time of filling out the daily assessment. Data from these days were removed prior to analysis. Participants reported alcohol use on the previous day on 23.5% of days ($M_{number\ of\ drinks}$ = 4.20), meaning our participants reported roughly 1.5 drinking episodes per week on average. This means that participants drank slightly less relative to most daily alcohol use studies among college

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

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

[5] This smallest effect size of interest was also based on the distribution of O_{max} values in cross-sectional data, and we do not believe it is sensible in the data at hand.

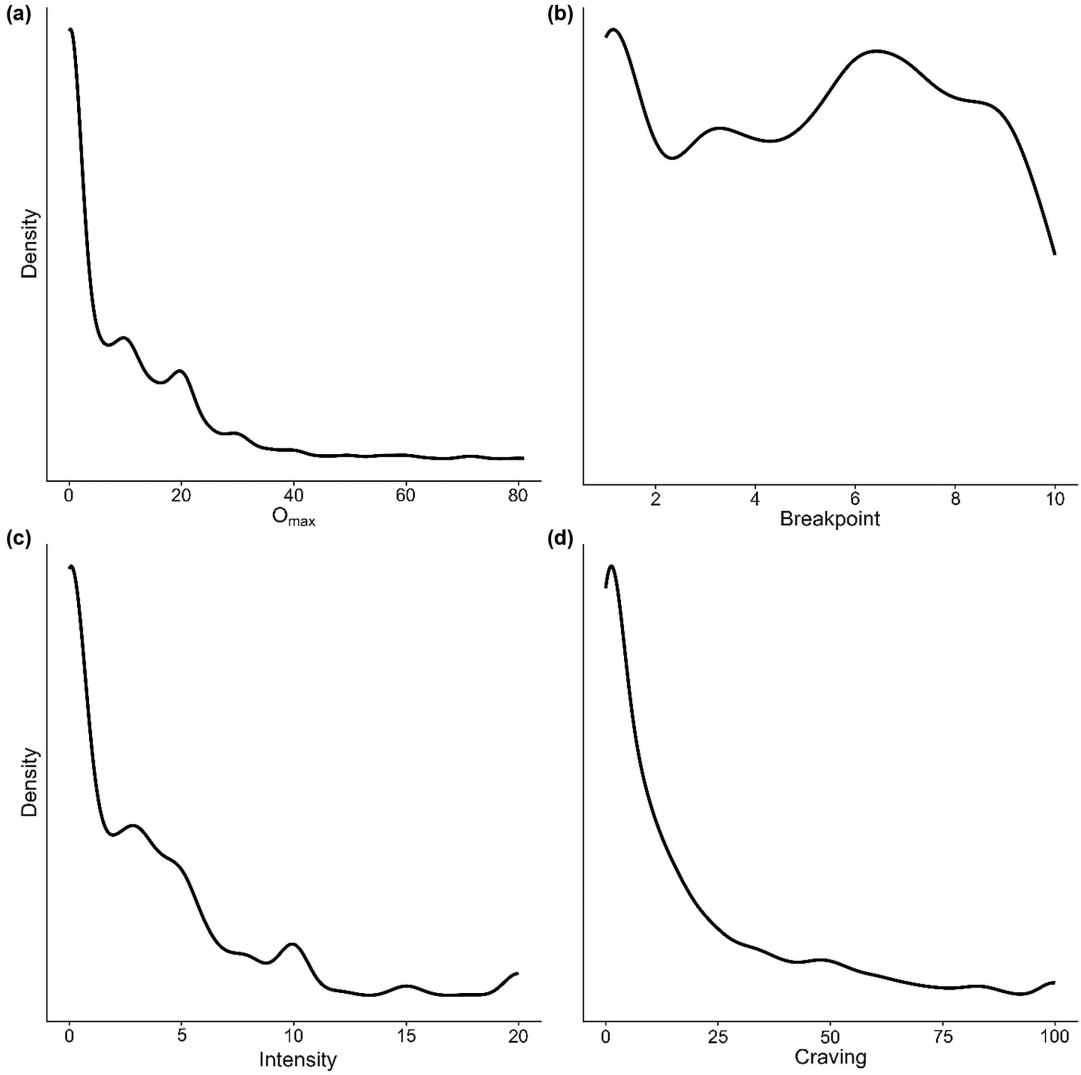
students, where participants tend to drink on 30%–40% of days and drink about 5–6 drinks per drinking episode on average (Dora, Piccirillo, et al., 2023). The distributions of daily O_{max} (maximum amount of money spent on alcohol), breakpoint (price at which participant no longer indicated to consume any alcohol), intensity (number of drinks consumed when alcohol is free), and self-reported craving are visualized in Figure 1.

Manipulation Check

On average, participants' self-report of feeling upset increased by 10.46 points (SD = 23.38) following the negative mood induction and decreased by 0.22 points (SD = 15.54) following the neutral mood induction (Cohen's d = 0.53). Figure 2 visualizes this manipulation check and highlights that for many participants, mood did not change much following either mood induction, and some participants even reported a larger increase in feeling upset after a neutral (compared to negative) mood induction. This indicates that the mood manipulations were not as successful in our sample compared to previously reported studies (e.g., when converting the effect size reported in Verheyen & Goritz, 2009, in their study the text mood induction resulted in Cohen's d = 0.69; in our study, the strength of the text mood induction alone was Cohen's d = 0.41).On average, the picture mood inductions were more effective than the text and Velten mood inductions. Participants' self-repot of feeling upset increased on average by 17.09 points following the negative picture mood inductions but only by 6.43 and 7.97 points following the negative text and Velten mood inductions, respectively. All neutral mood inductions resulted in little change on average ($M_{picture}$ = −0.25, M_{text} = −1.02, M_{Velten} = 0.39).

Figure 1

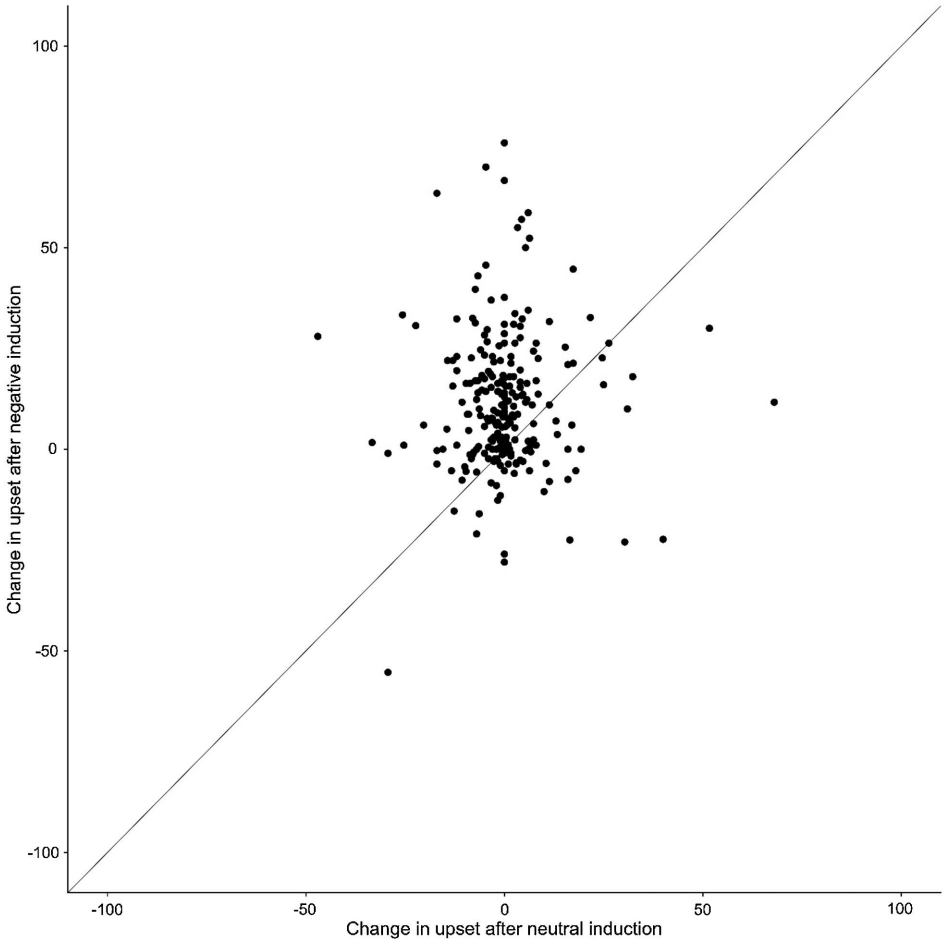
Distribution of O_{max} (a), Breakpoint (b), Intensity (c), and Self-Reported Craving (d)



Note. O_{max} reflects the maximum amount of money (in $) one would spend on alcohol on that day, breakpoint reflects the first price (in $) at which one would not consume any alcohol, and intensity reflects the number of drinks consumed when cost is $0.

Figure 2

Scatterplot Where Each Dot Represents One Participant



Note. Participants above (below) the diagonal became more upset on average following a negative (neutral) mood induction.

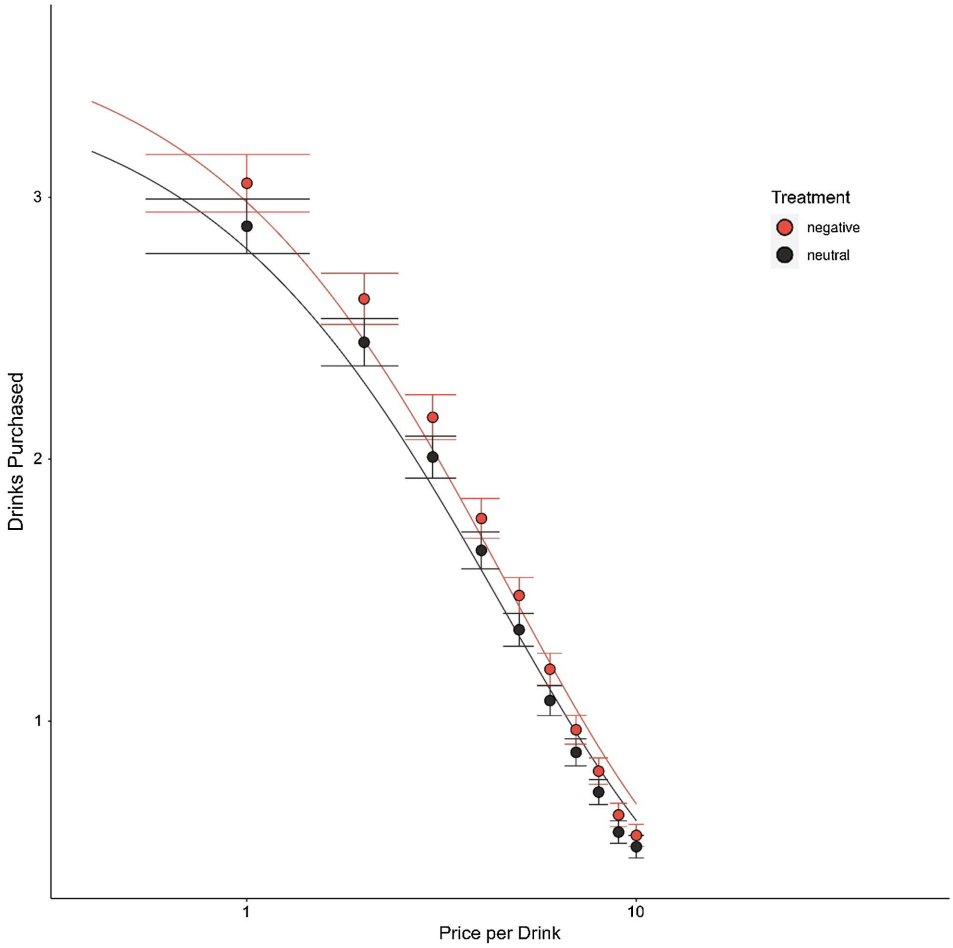
Preregistered Analyses

Figure 3 shows the demand curve derived from the APT data separately for the negative and neutral mood induction (treatment). Figure 4 shows a posterior predictive check highlighting that a linear model with a Gaussian outcome distribution does not accurately model daily O_{max} values and a posterior predictive check of a more appropriate hurdle model, which we used to model our data after realizing the mistake in our a priori assumptions. We do not believe that interpreting the model parameters of the Gaussian model is valid, which is why here, we report only the findings of the more appropriate model. While this is a deviation from our preregistered plan, we hope Figure 4 conveys the necessity of this deviation.

The results from our preregistered analyses are summarized in Table 2. As we a priori did not intend to predict the likelihood of O_{max} values being larger than 0 but were interested in the effect of our predictors on the size of O_{max} values, we focus our interpretation on the parts of our model in which we predict the size of the O_{max} values (readers can find the hurdle parameters, which were necessary to adequately model the data, in Table 2). The data indicate strong statistical evidence in favor of the null hypothesis over an effect of the negative mood inductions on O_{max} (95% CI [−0.10, 0.23], $BF_{01} = 84$), which indicates that participants were not willing to spend more money on alcohol following the negative (vs. neutral) mood inductions. Similarly, the data did not indicate evidence for any of our interaction hypotheses, as indicated by the narrow 95% credible intervals around 0. Thus, the effect of negative mood inductions on O_{max} values was not stronger for participants who report heavier drinking nor on days participants reported higher coping motives or negative urgency. We did observe two sizeable main effects on O_{max} that had nothing to do with our mood inductions, namely that O_{max} values were elevated for people who report heavier drinking and on days participants reported higher coping motives. The main effects of our mood inductions, baseline alcohol consumption, and daily coping motives are visualized in Figure 5. The conclusions from our confirmatory analyses did not change in our preregistered sensitivity analyses where we (a) removed data from days following alcohol use and (b) controlled for alcohol use on the previous day. These sensitivity analyses are summarized in the additional online materials that can be found at https://osf.io/fks3j/.

Figure 3

The Demand Curve Shows How Drinking Is Suppressed as the Price Increases Split by Mood Induction



Note. See the online article for the color version of this figure.

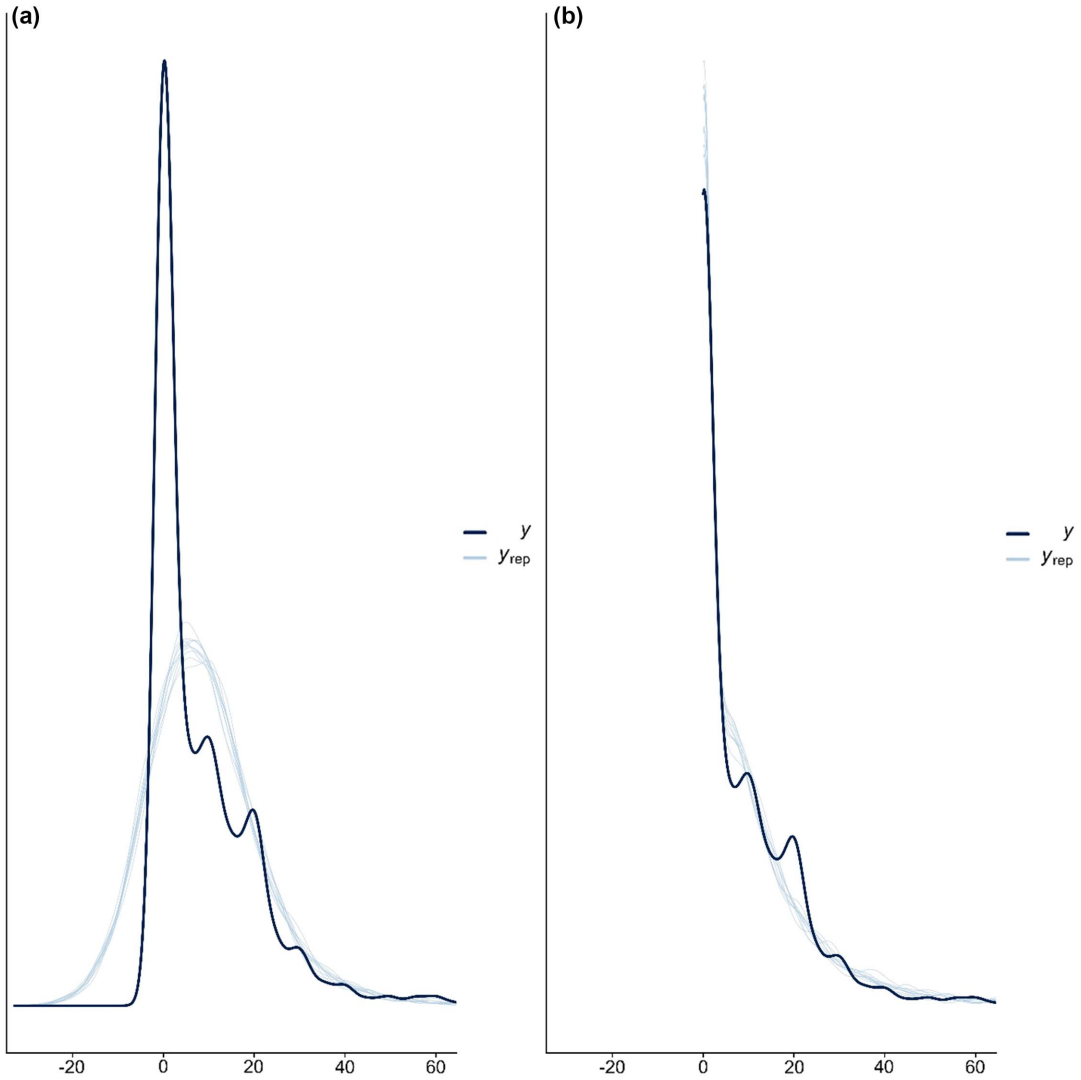
We also preregistered exploratory models in which we predicted intensity, breakpoint, and self-reported craving. Results from these models are summarized in Table 3. The mood induction did not predict intensity, breakpoint, or craving. The results indicate for the most part that these effects were not moderated by alcohol consumption, daily coping motives, or daily negative urgency. Based on the 95% CI of the interaction parameter, one exception was possibly the interaction between the mood induction and daily negative urgency on craving. We calculated a conditional effect of the mood induction on craving for daily negative urgency values one standard deviation above and below the mean. On days below the mean, participants reported slightly elevated alcohol craving following the negative (vs. neutral) mood induction (estimate = 0.13, 95% CI [−0.09, 0.34]), while on days above the mean, participants reported minimally lower alcohol craving following the negative (vs. neutral) mood induction (estimate = −0.04, 95% CI [−0.26, 0.18]). Given that this effect, if at all, is opposite to what we would predict (we would expect the effect of the negative mood induction on craving to be stronger on days participants report higher negative urgency) paired with the uncertainty around the estimates, we believe this most likely to be a chance finding. People who report heavier drinking on average indicated wanting to consume more drinks when they are free (intensity) but did not have higher breakpoint values or report higher craving. Daily coping motives robustly predicted increases in all three outcomes.

Non-pre-registered Sensitivity Analyses

The results from our preregistered analyses suggest that the behavioral economic demand for alcohol is not elevated following negative (vs. neutral) mood inductions. However, at this point we are wary of this conclusion for two reasons. First, we observed considerable variability in the effectiveness of our mood inductions (see Figure 2). A more variable and overall weaker manipulation could explain the lack of an effect here compared to previously reported results among studies that were published (Amlung & MacKillop, 2014; Owens et al., 2015; Rousseau et al., 2011). Second, Figure 5a indicates that O_{max} values were slightly higher following the negative mood induction on average, though the

Figure 4

Posterior Predictive Check of A Priori-Specified Gaussian Model (a) and Post Hoc–Specified Hurdle Model (b)



Note. The posterior predictive check indicates the extent to which the model is able to simulate data (y_{rep}) that are comparable to the observed data (y). See the online article for the color version of this figure.

overlap was sufficient to suggest statistical evidence in favor of the null hypothesis. It could be that the effect was stronger when the mood inductions worked as intended. For that reason, we decided to perform two non-pre-registered sensitivity analyses.

First, we reran our preregistered analyses on a subset of the data where the mood inductions worked as intended, that is where the negative mood induction resulted in an increase in feelings of upset of more than 5 points and the neutral mood induction resulted in no comparable increase in feelings of upset (so, resulted in a decrease in feelings of upset, no change, or an increase up to 4 points; Cohen's d = 2.24). This was the case on 51.5% of days (see Figure 6a). We chose these values arbitrarily but only performed one such analysis, which we report here (i.e., we did not run this analysis with 5, 10, 15, … points and reported the analysis that was most convenient for us). This non-pre-registered sensitivity analysis is visualized in Figure 6b. In this subset, the BF indicates that the data are roughly 15 times more compatible with an effect of the mood inductions on O_{max} compared to the null hypothesis of no such effect (95% CI [0.01, 0.29], BF_{10} = 15.60).

Second, we predicted O_{max} values from a change score (post-induction − preinduction) in feelings of upset. The rationale behind this analysis is similar, in that we should expect that O_{max} values should increase more the more upset a participant became. This analysis also indicated evidence in favor of an effect of negative mood on O_{max} (95% CI [0.03, 0.08], $BF_{10} > 30$) and is visualized in Figure 6c.

Table 2
Parameters, Estimates, and 95% Credible Intervals for Our Preregistered Analyses

Parameter	Estimate	[95% CI]
Hurdle intercept	−0.62	[−1.02, −0.23]
Hurdle mood induction	−0.01	[−0.36, 0.35]
Hurdle alcohol consumption	0.32	[0.01, 0.63]
Hurdle Mood Induction × Alcohol Consumption	−0.06	[−0.28, 0.16]
Hurdle coping motives	−0.34	[−0.50, −0.18]
Hurdle Mood Induction × Coping Motives	0.06	[−0.16, 0.29]
Hurdle negative urgency	0.00	[−0.16, 0.17]
Hurdle Mood Induction × Negative Urgency	−0.19	[−0.42, 0.04]
Intercept	2.28	[2.14, 2.42]
Mood induction	0.06	[−0.10, 0.23]
Alcohol consumption	0.13	[0.02, 0.23]
Mood Induction × Alcohol Consumption	−0.02	[−0.09, 0.04]
Coping motives	0.08	[0.04, 0.12]
Mood Induction × Coping Motives	−0.02	[−0.08, 0.03]
Negative urgency	0.02	[−0.03, 0.06]
Mood Induction × Negative Urgency	0.01	[−0.04, 0.07]

Note. Listed are first the effects on the likelihood of O_{max} being 0 (thus, negative estimates indicate a higher likelihood of O_{max} being larger than 0; e.g., the negative effect of coping motives on the hurdle parameter indicates that for participants reporting higher coping motives, O_{max} is more likely to be larger than 0), and then the effect on O_{max} values on days O_{max} was larger than 0. Hurdle parameter estimates can be interpreted as odds ratios predicting the odds of not endorsing the outcome, if exponentiated. CI = confidence interval.

Discussion

In this study, we set out to test whether people value alcohol more (operationalized as an increase in the behavioral economic demand for alcohol) following a negative emotional experience. Three previous studies (Amlung & MacKillop, 2014; Owens et al., 2015; Rousseau et al., 2011) tentatively supported this idea. We improved upon limitations of these studies with our study design, for example, by recruiting a larger sample, performing a repeated within-subjects test outside of the laboratory and by preregistering our analyses in detail. However, our study also ended up having one major limitation (a weaker mood induction compared to previous research), which complicates the interpretation of our results and the synthesis with the existing research.

In our preregistered analyses, contrary to previous research, we found strong evidence *against* the idea that the behavioral economic demand for alcohol is elevated following a negative (vs. neutral) mood induction. This was true in the overall sample (Hypothesis 1) but also true for people who report heavier drinking (Hypothesis 2) and on days participants reported higher coping motives (Hypothesis 3) and higher negative urgency (Hypothesis 4). *If* we can trust these results, we believe this would be quite damning for negative reinforcement models of alcohol use (Baker et al., 2004; Cox & Klinger, 1988; Koob & Le Moal, 2008); if a negative emotional event does not lead to a change in the valuation of alcohol immediately (which should be much easier to affect), it seems quite implausible that negative emotional events can have a causal effect on people's drinking behavior, given that the decision to drink will be influenced by many additional considerations.

However, these results are far from conclusive as the mood inductions in our study did not work as well as expected given prior research. On many days, participants did not report getting more upset after the negative mood induction, and on some days, they reported getting more upset after the neutral mood induction. We cannot say with certainty why the mood inductions worked less well than has been reported in previous research (Marcusson-Clavertz et al., 2019; Verheyen & Goritz, 2009). One possibility is that participants completed these mood inductions primarily on their laptop or PC in previous online studies just once, while in our study participants completed them multiple times mostly via their smartphone. It could be that the provided materials are less upsetting on a smaller screen, or alternatively it could be that these mood inductions work less well when participants are repeatedly exposed to variations of them over multiple days. Irrelevant of the reasons for this, the variability and overall weakness of the mood inductions pose a serious threat to our inferences; we should not expect a negative mood induction to predict increases in the behavioral economic demand for alcohol if on half of the days it did not result in higher negative affect, which was the case here.

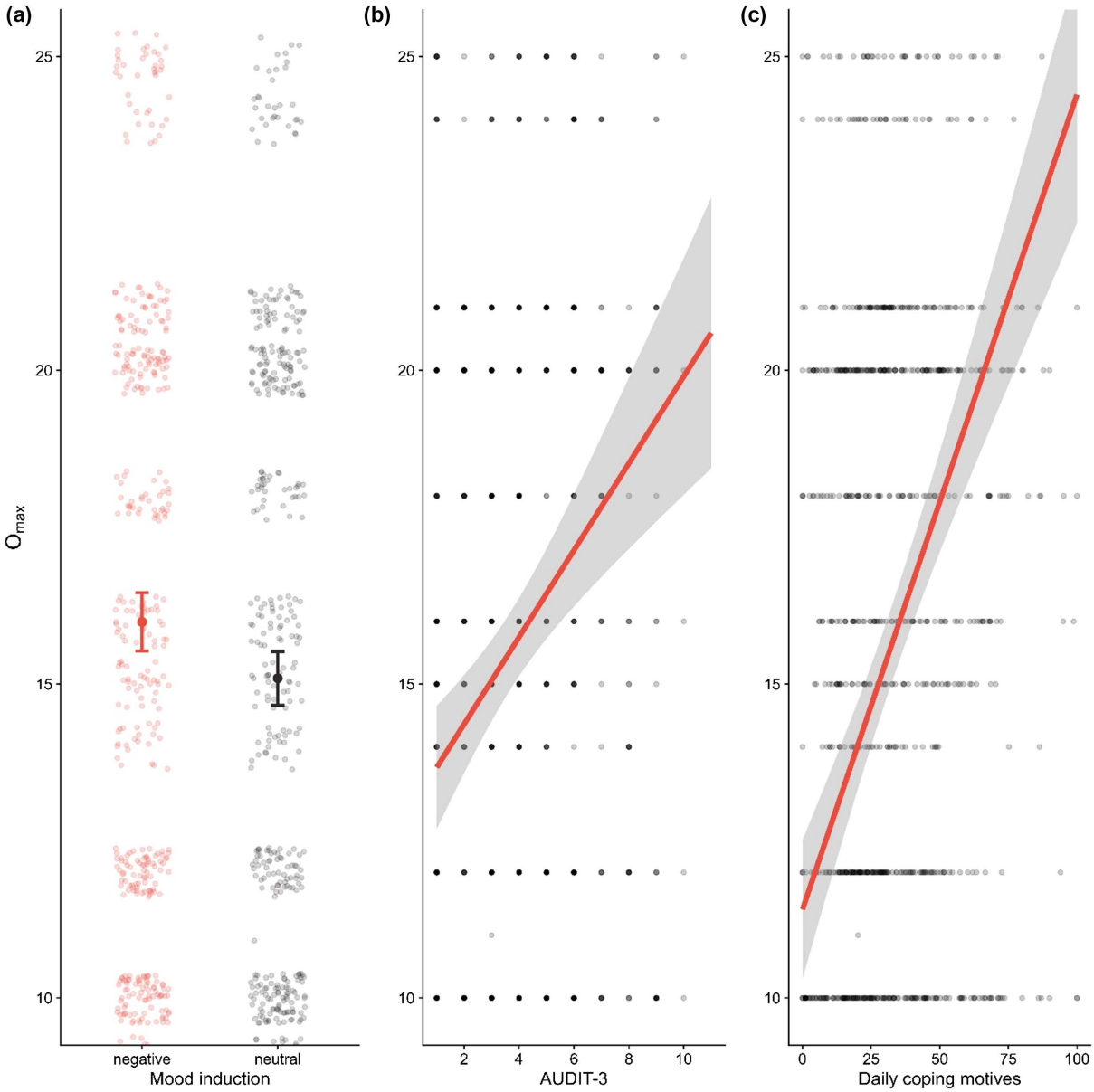
For this reason, we decided to perform two non-pre-registered exploratory analyses. Both analyses address the influence of the weakness of the manipulations by, respectively, focusing on days on which the mood inductions worked as intended and the reported subjective emotional experience. The results from both analyses contradict the results from our preregistered analyses and support the previously reported findings (Amlung & MacKillop, 2014; Owens et al., 2015; Rousseau et al., 2011) of negative mood on the behavioral economic demand for alcohol. Deciding which set of analyses to trust more is not straightforward. On the one hand, we know that deciding how to analyze one's data post hoc increases risk of bias even when the hypothesis was specified a priori (Gelman & Loken, 2013). This is an argument to favor our preregistered analyses. On the other hand, common sense implies that a manipulation of negative mood that does not reliably increase negative mood cannot be expected to have a robust effect on people's valuation and decision making. This is an argument to favor our exploratory analyses.

Results from our preregistered and exploratory analyses agreed that the effect of negative mood on the behavioral economic demand for alcohol likely is not stronger for people who report heavier drinking or on days characterized by higher coping motives or negative urgency. People who report heavier drinking had a higher behavioral economic demand for alcohol, as did participants in general on days they reported higher coping motives. While these results are generally unsurprising, the large effect of daily coping motives on O_{max} is noteworthy. These results mirror effects on daily alcohol use, where coping motives are associated with more frequent and heavier drinking, but this effect is not specific to days on which negative affect is high (Dora, Piccirillo, et al., 2023). Thus, the results here add to a body of literature (Bresin & Mekawi, 2021; M. L. Cooper et al., 2016; Dora, Kuczynski, et al., 2023; Waddell et al., 2021) that indicates that coping motives are a robust indicator of various drinking outcomes (such as alcohol use, alcohol consequences, and behavioral economic demand), even though they do not moderate the association between negative affect and these drinking outcomes.

We believe this study has several important takeaways for the field of alcohol use research. First, as discussed above, we conclude the data from this study slightly increase our confidence (though not as much as we had hoped) in the previously reported result that people value alcohol more immediately following a negative emotional experience. If this conclusion is correct, this has several

Figure 5

Main Effects of Mood Induction (a), Self-Reported Alcohol Consumption (b), and Daily Coping Motives (c) on O_{max}



Note. The *y*-axis can be interpreted as the maximum amount of dollars a participant was willing to spend on alcohol following either mood induction. AUDIT-3 = Average of the first three Alcohol Use Disorders Identification Test items, which measure drinking frequency and quantity. See the online article for the color version of this figure.

implications for affect regulation models of alcohol use (Baker et al., 2004; M. L. Cooper et al., 1995; Cox & Klinger, 1988; Koob & Le Moal, 2008). These models predict that people are more likely to drink and consume more alcohol in moments high in negative affect, which so far we see in the lab (Bresin et al., 2018) but not in studies in everyday life (Dora, Piccirillo, et al., 2023). We reasoned in the introduction that due to situational constraints, alcohol use primarily takes place on weekends and in the evening but that the momentary behavioral economic demand for alcohol might be more commonly influenced by negative emotional experiences. In some ways, we both did and did not observe this. One the one hand, O_{max} in our daily study clearly is very differently distributed than when participants are asked to imagine a typical drinking situation. This shows that alcohol demand, when measured as a momentary construct, is also very dependent on time and place (Miller et al., 2023), and that momentary and global alcohol demand reflect distinct cognitive

Table 3
Parameters, Estimates, and 95% Credible Intervals for Our Exploratory Analyses

Parameter	Intensity		Breakpoint		Craving	
	Estimate	[95% CI]	Estimate	[95% CI]	Estimate	[95% CI]
Hurdle intercept	−0.90	[−1.28, −0.50]			−2.28	[−2.82, −2.76]
Hurdle mood induction	−0.09	[−0.46, 0.30]			−0.02	[−0.54, 0.49]
Hurdle alcohol consumption	0.26	[−0.02, 0.55]			−0.03	[−0.39, 0.32]
Hurdle Mood Induction × Alcohol Consumption	0.01	[−0.19, 0.22]			0.18	[−0.08, 0.43]
Hurdle coping motives	−0.42	[−0.57, 0.26]			−0.42	[−0.61, −0.23]
Hurdle Mood Induction × Alcohol Consumption	0.12	[−0.10, 0.34]			0.03	[−0.24, 0.30]
Hurdle negative urgency	−0.04	[−0.21, 0.13]			−0.29	[−0.49, −0.08]
Hurdle Mood Induction × Negative Urgency	−0.08	[−0.31, 0.15]			−0.06	[−0.34, 0.23]
Intercept	1.29	[1.16, 1.42]	−0.03	[−0.17, 0.11]	2.45	[2.23, 2.66]
Mood induction	0.07	[−0.08, 0.21]	0.01	[−0.13, 0.15]	0.05	[−0.23, 0.31]
Alcohol consumption	0.15	[0.06, 0.23]	−0.05	[−0.18, 0.08]	0.05	[−0.06, 0.15]
Mood Induction × Alcohol Consumption	0.0	[−0.05, 0.05]	−0.03	[−0.13, 0.08]	−0.10	[−0.19, 0.01]
Coping motives	0.09	[0.06, 0.12]	0.09	[0.01, 0.16]	0.22	[0.16, 0.28]
Mood Induction × Coping Motives	−0.02	[−0.06, 0.03]	−0.07	[−0.18, 0.04]	0.01	[−0.08, 0.10]
Negative urgency	0.04	[0.00, 0.07]	−0.01	[−0.09, 0.06]	0.19	[0.12, 0.26]
Mood Induction × Negative Urgency	0.00	[−0.05, 0.05]	−0.02	[−0.13, 0.09]	−0.08	[−0.18, 0.01]

Note. Listed are first the effects on the likelihood of intensity and craving being 0 (thus, negative estimates indicate a higher likelihood of intensity and craving being larger than 0; breakpoint was not zero-inflated so no mixture model was used to analyze breakpoint), and then the continuous effect on intensity, breakpoint, and craving. CI = confidence interval.

processes. This should not be surprising, given that prior work has also suggested that other cognitive constructs like cravings also exhibit reactivity to contextual constraints (Meisel et al., 2023). On the other hand, our study indicates that alcohol demand might increase after a negative emotional experience.

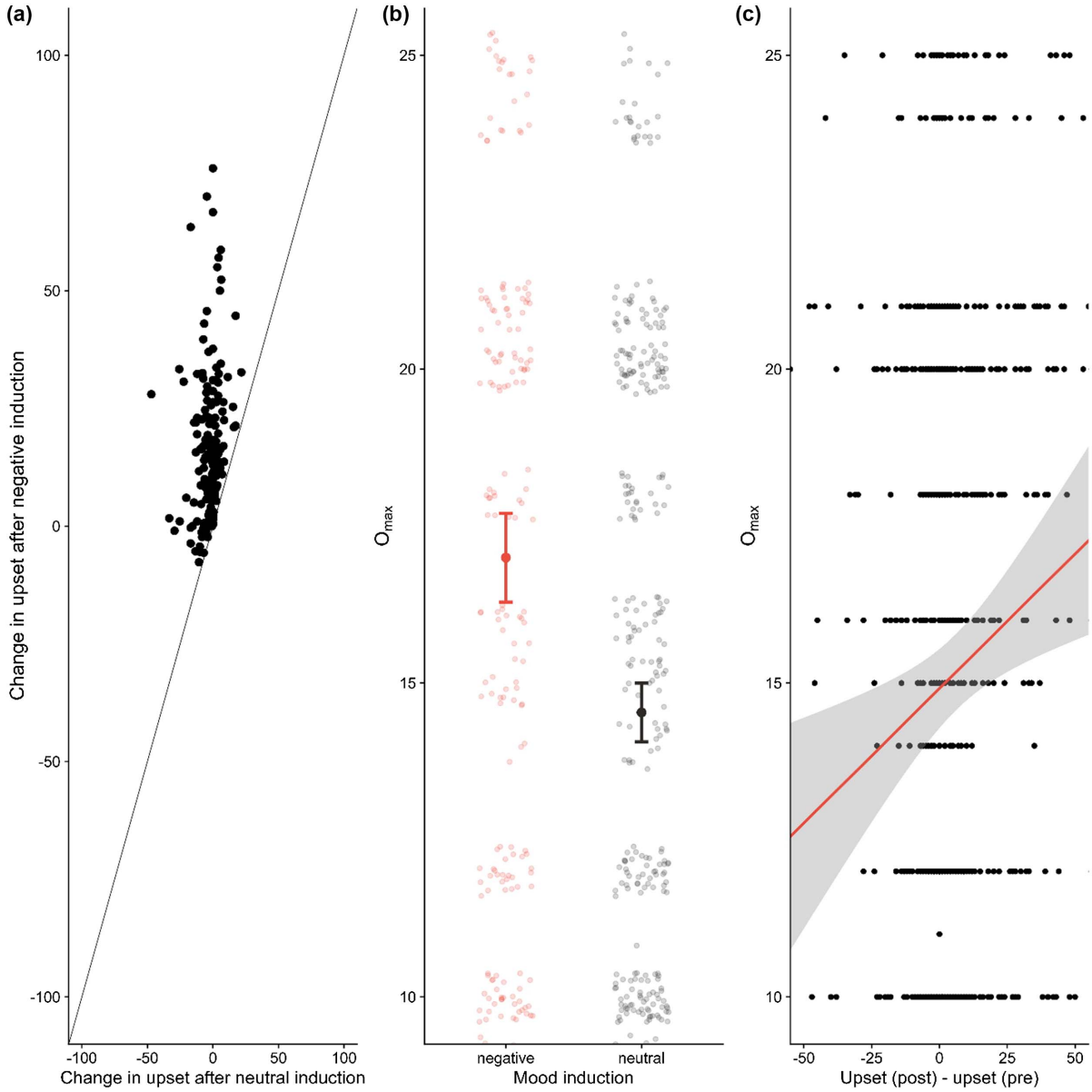
There are several plausible explanations for this divergence. It could be that the value of alternative emotion regulation strategies increases in parallel or perhaps even more so than the value of alcohol. As people often have multiple options to attempt to regulate their negative affect and should select the option that has the highest *relative* value, focusing exclusively on the absolute value of alcohol (as we have done here via the APT) might miss the bigger picture. In general, we do not have much data on how alcohol use might function as an emotion regulation strategy in the context of alternative strategies. To this end, it might be valuable to conduct more studies in which the value of alternative emotion regulation strategies is assessed in parallel, or perhaps even where participants are asked to make decisions between alcohol and an alternative in moments high in negative affect (Dora, Copeland, et al., 2023; Hogarth et al., 2018; Hogarth & Hardy, 2018). Relatedly, even if the value of alcohol increases more than that of alternatives in these moments, in everyday life people often do not have access to alcohol immediately following a negative emotional event. Thus, people might have already regulated their negative emotions via alternatives by the time they have an opportunity to consume alcohol. Here, it might make sense to explore whether negative mood impacts the decision to consume alcohol in a subset of negative emotional experiences where people have access to alcohol (Acuff et al., 2020).

Second, in hindsight two design choices stand out. In this study, we used several mood induction procedures that, based on previous research, should be effective in online studies (Marcusson-Clavertz et al., 2019; Verheyen & Goritz, 2009). However, our study differed from these previous studies in two potentially important ways; participants mostly completed our study on their smartphone, and we repeatedly exposed participants to varying mood inductions over 12 days. We learned that these differences might impact the effectiveness of the used mood inductions, and so we learned that in the future, we should pilot more extensively when adapting methods. We also asked participants to complete a momentary variation of the APT every day, whereas most cross-sectional research asks participants to imagine a typical Friday night out. This highlights the strong effect of the day of the week on outcomes related to alcohol. Whereas in cross-sectional research, O_{max} tends to be normally distributed, in our study, it was heavily zero-inflated. Even for heavy-drinking young adults, the behavioral economic demand for alcohol is likely very low on a Monday. Thus, it might often make sense to limit daily studies such as this one to only a few days of the week when alcohol use is far more likely (e.g., Thursday–Sunday).

In summary, this study adds to a body of literature (Acuff et al., 2020; Bresin et al., 2018; Dora, Copeland, et al., 2023) that shows that negative mood might have an immediate effect on cognitions and decisions surrounding alcohol. This is intriguing, as people are not more likely to drink and do not consume more alcohol on days they experience higher negative affect (Dora, Piccirillo, et al., 2023). The combination of these results suggests to us that the affect regulation hypothesis remains plausible but that we do not understand the full picture yet. More careful research is needed to understand under which conditions negative affect is a risk factor for heavy drinking and the development of alcohol use disorder.

Figure 6

Feelings of Upset in Subset of Data (a), Effect of Mood Induction on O_{max} in This Subset (b), and Effect of Change in Feelings of Upset on O_{max} (c)



Note. See the online article for the color version of this figure.

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