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Testing the robustness of daily associations of affect with alcohol and cannabis use

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Abstract

Etiological models of alcohol and cannabis use disorders hypothesize that people are more likely to use substances when experiencing heightened negative affect, yet recent EMA studies found no evidence for this daily association. To provide a robust understanding of whether and when affect regulation is supported in EMA, we tested within-person associations between affect and substance use across hundreds of statistical models in a diverse sample of young adults (N = 496)

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The authors declare no competing interests.

Code availability
All code is available at https://osf.io/fm6cq/.

recruited from both college and community sources, aged 18–22 years (55.8% assigned female sex at birth, 44.2% assigned male sex at birth; 47.2% cisgender female, 43.8% cisgender male, 12.9% nonbinary/genderqueer/gender non-conforming, 4.0% transgender; 69.6% non-Hispanic White, 26.2% Asian, 6.7% African American, 8.5% Hispanic/Latino). Using specification curve analyses, we examined how different affect operationalizations, time scales, and moderators influenced these associations. For alcohol use, higher negative affect predicted decreased likelihood of drinking (median OR = 0.95, $p < .001$), with 20.6% of specifications reaching significance. This counter-intuitive pattern was strongest for sadness and when examining maximum daily negative affect. Surprisingly, and contrary to theoretical predictions, this negative association was slightly more pronounced among those with higher coping motives and at lower levels of AUD symptoms. Positive affect showed a complex pattern, with high-arousal states like joviality strongly predicting increased drinking likelihood, while low-arousal states showed weaker associations. Neither affect type consistently predicted drinking quantity. For cannabis use, neither positive nor negative affect predicted use likelihood or quantity across specifications. These associations remained consistent regardless of substance use disorder severity or social context. Our findings challenge core assumptions of affect regulation models and suggest that, at least in young adults, the affect-substance use relationship is more nuanced than previously theorized, with implications for refining etiological models.

Introduction

Hundreds of millions of people around the world regularly consume alcohol and cannabis (United Nations, 2022; World Health Organization, 2019). Although moderate consumption of these substances likely is not associated with severe negative outcomes for the majority of the population (Poli et al., 2013; Terry-McElrath et al., 2017), excessive use is robustly associated with adverse health consequences such as cardiovascular diseases (Holmes et al., 2014), liver cirrhosis (Rehm et al., 2010), and impaired memory and attention (Dellazizzo et al., 2022). According to the 2021 National Survey on Drug Use and Health, 28.6 million adults aged 18 and older met criteria for alcohol use disorder and 15.0 million adults aged 18 and older met criteria for cannabis use disorder in the United States alone (SAMHSA, 2021). As a consequence, excessive use of these substances contributes to poor health and the death of millions of people globally (World Health Organization, 2018), resulting in economic costs exceeding one percent of the gross national product of high- and middle-income countries (Rehm et al., 2009).

A fundamental hypothesis about the etiology of alcohol and cannabis use disorders is that people are more likely to use and consume more alcohol and cannabis when they experience negative affect. This is because both substances are thought to improve people's mood (i.e., reduce negative affect and/or increase positive affect) (Cooper et al., 1995; Cooper et al., 2016; Cox & Klinger, 1988) and this affect regulation is thought to be one common pathway to substance use disorder (Baker et al., 2004; Koob & Le Moal, 2008). This idea has influenced the design of interventions aimed at improving affect regulation in order to prevent the development of substance use disorders (Stasiewicz et al., 2013) as well as interventions aimed at reducing substance use in community populations (Kelly et al., 2010; Vinci et al., 2014; Witkiewitz & Villaroel, 2009). In the past 20 years, according to NIH

RePORTER, the National Institute on Alcohol Abuse and Alcoholism alone has invested nearly $200 million across 551 research project grants which refer to *affect regulation* in the title or abstract. Thus, one might expect to observe strong evidence that negative affect motivates alcohol and cannabis use.

When asked *why* they consume alcohol and cannabis, people will often respond that they use these substances to regulate their emotions (Bonar et al., 2017; Cooper, 1994; Kuntsche et al., 2005; Lee et al., 2007; Simons et al., 1998), and people reporting higher coping and enhancement motives tend to consume more of these substances compared to other people (Bresin & Mekawi, 2019, 2021). Because people have poor insight into the causes of their own behavior (Feil et al., 2020; Mazar & Wood, 2022; Nisbett & Wilson, 1977; Todd et al., 2004) and because such cross-sectional research tests between-person differences (whereas affect regulation models primarily predict within-person effects), global self-reports do not provide strong evidence that people consume more alcohol and cannabis *on days or in moments* they experience higher negative affect. Laboratory experiments do show that negative mood inductions robustly lead to momentary increases in alcohol use (d_{avg} = .31) (Bresin et al., 2018), but only in the specific situation simulated in the laboratory (e.g., when alcohol is freely available immediately following a negative emotional experience and when drinking would have no impact on later responsibilities) (de Wit et al., 2003)[1]. Evidence from everyday life is therefore needed to apply affect regulation models to understanding the etiology of substance use disorders, and determine whether just-in-time interventions can potentially be effectively deployed based on people's affective states (Piasecki, 2019; Shiffman, 2009).

Research examining the link between affect and substance use in everyday life has failed to produce robust evidence favoring affect regulation hypotheses. To study whether people are more likely to use and consume more alcohol and cannabis on days they experience higher negative affect, researchers frequently use the Ecological Momentary Assessment (EMA) research design, in which people report on their emotional state multiple times throughout the day and report on their substance use either in the evening or the following morning for multiple days or weeks (Shiffman et al., 2008). EMA studies test the temporally-sequenced, within-person association between affect and substance use while maximizing ecological validity and minimizing recall bias (Hopwood et al., 2021; Kaurin et al., 2023). Although EMA studies have occasionally reported negative affect to be associated with alcohol use (Dvorak et al., 2014; Kashdan et al., 2010; Park et al., 2004) and cannabis use (Buckner et al., 2012, 2013; Shrier et al., 2014) on the daily level, these associations were weak, with the vast majority of studies reporting null associations. In a recent preregistered meta-analysis of individual participant data from more than 12,000 participants observed on over 350,000 participant-days (including data from the majority of EMA studies in this literature), we found no evidence that people were more likely to use alcohol or to consume more alcohol on days when they experienced heightened negative affect (Dora, Piccirillo, et al., 2023). Further, there was no association between negative affect and alcohol use even for individuals who self-reported that they tend to drink in response to negative affect. Although

[1]We are not aware of any experiments testing the effect of mood inductions on cannabis consumption.

no meta-analysis of the daily associations between negative affect and cannabis use has yet been performed, a narrative review concluded that the evidence is mixed for non-clinical samples of regular cannabis users (Wycoff et al., 2018). The majority of studies (especially those with larger sample sizes) have reported that negative affect is not meaningfully (or negatively) associated with cannabis use on the daily level (Chakroun et al., 2010; Dora, Smith, et al., 2023; Testa et al., 2019; Wycoff et al., 2018).

Although the current evidence seriously challenges the affect regulation theory of the etiology of alcohol and cannabis use disorders, it has not conclusively falsified the hypothesized association between negative affect and alcohol or cannabis use in everyday life for two major reasons. First, theoretical models differ with regards to the population in which they expect to find an association between negative affect and substance use. Some models do not specify a specific population in which we should expect to find an association between negative affect and substance use (Cooper et al., 1995; Cox & Klinger, 1988). Other models specify that we should expect this effect specifically in *individuals with substance use disorder symptoms or advanced substance use disorder severity* (Baker et al., 2004; Koob & Le Moal, 2008). In prior research on alcohol and cannabis use (including our own), there are very few studies that explicitly sampled people with alcohol or cannabis use disorder or were in treatment for these disorders because most studies relied on community and college samples (for an exception, see Walsh et al., 2023), and few included measures of alcohol or cannabis use disorder symptoms as a moderator. Thus, it is unclear to what extent prior research generalizes to people varying in substance use disorder symptoms or severity.

Second, theoretical models do not clearly operationalize (1) substance use, (2) negative affect, or (3) the time scale at which negative affect should be associated with substance use, rendering falsification difficult (van Rooij & Baggio, 2021). For example, in our meta-analysis, we posed the core hypothesis that *negative affect is associated with subsequent alcohol use on a daily level, so that people are more likely to use and consume more drinks on days they report higher negative affect*, but we could only falsify this hypothesis in a few limited ways, mainly finding that (1) neither the likelihood of alcohol use nor the quantity of alcohol consumed is predicted by (2) general negative affect[2] (3) averaged throughout the day (Dora, Piccirillo, et al., 2023).

Perhaps unsurprising given the theoretical ambiguity, the hypothesis that negative affect is associated with alcohol use and cannabis use has been tested in many additional ways across the literature. For example, some studies tested whether general levels of negative affect are associated with substance use (Armeli et al., 2010; Buckner et al., 2013; Dora et al., 2022), while others have predicted alcohol and cannabis use from more specific affective states such as anxiety (Buckner et al., 2012; Dvorak & Simons, 2014), depressed mood (Chakroun et al., 2010), anger (Gruber et al., 2012), or hostility (Trull et al., 2016). Some studies have tested whether negative affect averaged throughout the entire day (but prior to the onset of substance use) is associated with substance use (Dora et al., 2022; Stevenson et al., 2019; Waddell et al., 2022), whether affect reported during the EMA survey most proximal to the onset of use predicts substance use (Chakroun et al., 2010; Stevens et al., 2021), or

[2]Operationalized as a mean score of all negative emotion items assessed in an EMA study.

whether variability in negative affect throughout the day predicts substance use (Gottfredson & Hussong, 2013; Mohr et al., 2015; Shadur et al., 2015). Some studies predicted the daily likelihood of consuming alcohol or cannabis (Dora, Smith, et al., 2023; Dvorak et al., 2018), while others predicted the quantity of alcohol or cannabis consumed (Mohr et al., 2001; Stevenson et al., 2019). The result is a set of studies testing one interpretation of affect regulation at a time, producing inconsistent conclusions regarding the core hypothesis with no ability to determine whether and when it is best supported.

Despite the vast amount of EMA data that indicate that people are not more likely to use alcohol in response to negative affect, the hypothesis that negative affect is associated with substance use on the daily level remains plausible. Even if, as evidenced by our prior work, general negative affect averaged throughout the day is not associated with later same-day likelihood or quantity of alcohol or cannabis consumed, one of many other ways in which the hypothesis can be translated into a statistical test may show that this association does exist. Perhaps it exists for only one or a few negative affective states (e.g., for anxiety but not sadness), only at one specific time scale (e.g., negative affect experienced close in time to the onset of using), or only for a subset of the population (e.g., people with substance use disorder symptoms). This remains plausible especially given that our meta-analytic results do not converge with people’s self-reports, evidence from experimental studies, and research on other risky and unhealthy behaviors that are predicted by negative affect in EMA research such as binge eating (Haedt-Matt & Keel, 2011), smoking (Akbari et al., 2020), and engaging in self-injurious thoughts and behaviors (Kuehn et al., 2022).

On the other hand, our meta-analysis and additional empirical EMA work indicate that positive affect reported throughout the day is associated with an increased likelihood to consume alcohol and cannabis (Dora, Piccirillo, et al., 2023; Dora, Smith, et al., 2023; Howard et al., 2015; Stevenson et al., 2019), though also here null results are occasionally reported (Bold et al., 2017; Emery et al., 2021). On a theoretical level, less attention has been placed overall on positive compared to negative affect predicting problematic substance use. One likely reason for this is that coping with negative affect is not possible without experiencing (high) negative affect prior to use, but it is possible to enhance positive affect without experiencing (high) positive affect prior to use. One exception is the theoretical model by Koob and Le Moal (Koob & Le Moal, 2008), which specifies that substance use in regular users who have not (yet) developed a substance use disorder is primarily motivated by positive affect. This might be due to substance use mostly taking place in social and celebratory contexts, which people attend more frequently and enjoy more when positive affect is high (Isen, 1987; Kirkpatrick & De Wit, 2013). It is also broadly consistent with the externalizing pathway to substance use disorder (King et al., 2004; Tarter et al., 1999). This paired with the stronger evidence warrants more careful empirical work to understand the robustness of positive affective states motivating daily substance use.

A solution to this current state of uncertainty is to simultaneously test the affect regulation hypothesis of alcohol and cannabis use in everyday life in many reasonable ways. We identified one major difference in the underlying theory (negative affect predicting substance use in the population of regular users vs. only in the subset of substance users with symptoms of substance use disorder) and three major differences in empirical tests (operationalization of affect, operationalization of time scale, operationalization of substance use). The goal of the current study was to investigate these differences[3] to either gain confidence in the conclusion that positive but not negative affect is associated with subsequent same-day alcohol and cannabis use, or to learn under which conditions (if any) these association do exist. The results should enable us to make principled decisions regarding a formal update of affect regulation theory (Robinaugh et al., 2021), which currently is not possible, but clearly necessary.

First, we varied how affect is operationalized. We modeled likelihood and quantity of alcohol and cannabis use from nine affective states (five negative, four positive) which vary in both valence and arousal. This is important given that some research suggests that valence and arousal might have differential effects on people's subjective experience and decision-making (Blanchette & Richards, 2010; Kuppens et al., 2013). Moreover, the vast majority of EMA research on affect regulation has relied on the PANAS (Watson et al., 1988), which was designed to measure high arousal negative or positive affect, meaning relatively little is known about the role of low arousal affect. Two recent studies (Dora, Smith, et al., 2023; Emery et al., 2023) indicated that alcohol and cannabis use might be differentially predicted by different affective states, however these studies included a limited number of affect items. Second, we tested affect associations with alcohol and cannabis use across four different time scales. This should clarify whether associations between affect and alcohol and cannabis use are stronger or weaker when affect is reported closer in time to the onset of use (as affect might be a stronger motivator when it is proximal in time to access to alcohol/cannabis), when the highest level of affect reported any time prior to the onset of use is modeled (as intense affect might be motivating even when the average throughout the day is low), or when the variability in affect reported throughout the day is modeled (as affect variability is considered an indicator of emotional dysregulation that might motivate substance use (Mohr et al., 2015)), compared to affect averaged throughout the day prior to onset of use. Third, we modeled whether associations between affect and substance use differ for people with varying substance use disorder symptoms, as suggested by two prominent theoretical models (Baker et al., 2004; Koob & Le Moal, 2008). In regards to the former, given existing differences in the literature defining SUD symptoms and how they are operationalized (Boness et al., 2021; Watts et al., 2021), we will explore the robustness of our findings for multiple operationalizations of SUD symptoms. In regards to the latter, while we found no evidence that coping and enhancement motives moderate the association between positive/negative affect and alcohol use in our meta-analysis (Dora, Piccirillo, et al., 2023), the central role drinking motives play in the theoretical framework of affect regulation models (Cooper et al., 1995; Cooper et al., 2016) warrants testing whether such null results replicate across various operationalizations of affect and time scales. Lastly, we modeled whether associations between negative/positive affect and substance use differ on days when people engage in social and solitary substance use, since some research has indicated that negative affect might be a stronger motivator for solitary substance use (Creswell, 2021; Creswell et al., 2014; Skrzynski & Creswell, 2021).

[3]With the exception of the operationalization of substance use, as we consider predicting the likelihood of use and quantity of consumption to provide the most important information while being most reflective of the data generating process where people first decide whether to use and then how much to consume.

We tested the following hypotheses across several hundred justifiable model specifications (see Table S1 for details):

Hypothesis 1: Negative affect is associated with subsequent alcohol use, so that people (a) are more likely to use and (b) consume more alcohol on days they experience higher negative affect.

Hypothesis 2: Positive affect is associated with subsequent alcohol use, so that people are (a) more likely to use and (b) consume more alcohol on days they experience higher positive affect.

Hypothesis 3: Negative affect is associated with subsequent cannabis use, so that people are (a) more likely to use cannabis and (b) consume more cannabis on days they experience higher negative affect.

Hypothesis 4: Positive affect is associated with subsequent cannabis use, so that people are (a) more likely to use cannabis and (b) consume more cannabis on days they experience higher positive affect.

Methods

Ethics information

The study was approved by the University of Washington's IRB under Study ID 00006424. All participants provided informed consent and were paid $50 for completing the baseline survey, $1 for each completed EMA survey, and a $5 bonus for each week they completed at least 80% of EMA surveys.

Design

Following screening and training on the EMA protocol, participants first completed a baseline assessment. For the next 8 weekends (Thursday to Sunday), five times per day, participants received texts with a link to a brief EMA survey. Thus, participants contributed EMA data for 32 days. On Monday mornings, participants received an additional EMA to capture behavior from Sunday nights. EMAs were sent randomly within 5 three-hour blocks between 9am and 11pm, with at least one hour between surveys. Participants were initially sent one reminder at 30 minutes if they had not completed their survey; we changed this to 20- and 40-minute reminders after two months of data collection to increase participation rates.

Measures

Measures come from a more extensive battery. Below we report the measures relevant to the present study.

Alcohol and cannabis use

Participants reported on their prior day alcohol and cannabis use during morning EMA assessments, or at the second EMA assessment of the day in case the morning assessment was missed. Participants reported how many drinks they had the night before on a visual analogue scale ranging from 0 to 30 or more drinks. The scale was presented together with a definition of a standard alcoholic drink. Participants also reported how much cannabis they used on a visual analogue scale ranging from 0 to 28 grams. Substance use was reverse-lagged to line up with the affect assessments of the previous day. Participants also reported the time at which they started to use alcohol and cannabis on the previous day, which was used to establish temporal associations between our predictors and substance use.

Negative and positive affect

We included a total of 39 items in our study, each of which reflect one of seven affective states (anger, anxiety, sadness, distress, joviality, attentiveness, serenity; Table 1). At each EMA assessment, participants were randomly presented with two items from each of these seven states, for a total of 14 emotion items. We used this planned missing data design to reduce participant burden, increase data validity, and reduce unplanned missing data (Rhemtulla & Little, 2012; Silvia et al., 2014). Participants reported to what extent they experienced each emotion in the past hour on a visual analogue scale ranging from 0 = 'Not at all' to 100 = 'Very much'. Negative and positive affect variables showed high multilevel reliability across items and time (RkF_{NA} = .94, RkF_{PA} = .94).

Alcohol use disorder diagnostic criteria symptom indicators (AUDDCSI)

Participants completed the 33-item AUDDCSI (Boness et al., 2019) at baseline. Items referred to frequency of 11 different AUD criteria experienced in the past 12 months (3 items/symptoms per criterion). Example items included 'Did you find that you could drink a lot more before you got drunk?' and 'Driven a car when you knew you had too much to drink to drive safely?'. The response options ranged from 0 = 'Never' to 5 = '4+ times' in the past 12 months. In line with the original study (Boness et al., 2019), a symptom was coded as endorsed if it was reported 3 or more times in the past 12 months. A criterion was coded as present if at least one of the three corresponding symptoms was endorsed. These scales were developed based on an Item Response Theory model that showed good model fit in the original study (Boness et al., 2019).

Alcohol use disorder identification test (AUDIT)

Participants completed the 10-item AUDIT (Saunders et al., 1993) at baseline. Items referred to frequency during the past 12 months and included 'How often do you have six or more drinks on one occasion?' and 'How often have you been unable to remember what happened the night before because you had been drinking?'. We calculated one score indicating current alcohol use problems for each participant based on the AUDIT scoring manual (α = .81; ω = .87).

Drinking motives questionnaire (DMQ)

Participants completed the 20-item DMQ (Cooper, 1994) at baseline. Items asked how frequently the participant's drinking is motivated by each of the listed reasons and included 'To forget about your problems.' and 'Because it's fun.' (1 = 'Almost never/never' – 5 = 'Almost always/always'). We averaged the five coping items into one score of coping motives and the five enhancement items into one score enhancement motives (α_{coping} = .87, ω_{coping} = .93; $\alpha_{enhancement}$ = .90, $\omega_{enhancement}$ = .93).

Cannabis use disorder identification test-Revised (CUDIT-R)

Participants completed the 8-item CUDIT-R (Adamson et al., 2010) at baseline. Items referred to the frequency during the past 6 months and included 'How many hours were you stoned on a typical day when you had been using cannabis?' and 'How often have you had a problem with your memory or concentration after using cannabis?'. We averaged the 8 items into one score indicating current cannabis use problems for each participant (α = .86; ω = .90).

Marijuana motives questionnaire (MMQ)

Participants completed the 25-item MMQ (Simons et al., 1998) at baseline. Items asked how frequently the participant's cannabis use is motivated by each of the listed reasons and included 'To forget about your problems.' and 'Because it's fun.' (1 = 'Almost never/never' – 5 = 'Almost always/always'). We averaged the five coping items into one score of coping motives and the five enhancement items into one score enhancement motives (α_{coping} = .92, ω_{coping} = .94; $\alpha_{enhancement}$ = .94, $\omega_{enhancement}$ = .96).

Social context

Participants indicated who they were with the hour prior to filling out the last EMA survey of the day (alone vs with others). For analysis, we used the social context report that corresponded to the time of substance use onset on days when substances were used (i.e., if drinking started at the time of the 3rd survey of the day, we used the social context from the 3rd survey). For non-use days, we used the social context from the participant's median time of onset (i.e., if a participant typically started drinking around the 3rd survey, we used the social context from the 3rd survey on non-drinking days). This approach ensured that social context reports were temporally aligned with typical substance use patterns for each participant.

Sampling plan

The number of participants in this EMA study (n = 496[4]) was based on a power analysis for a different set of analyses than the ones reported here. For that reason, we conducted a set of simulations to determine the power we have to detect a main effect of affect conditional on the value of a moderator. We performed these simulations for predicting the number of alcoholic drinks consumed on drinking days, as this should be the analysis for which power was lowest, because this parameter in our mixture model relies on data from days on which participants drank alcohol. We had to make a few assumptions for these simulations. First, based on previous EMA research by our group (Dora et al., 2022; Dora, Piccirillo, et al., 2023; Dora, Smith, et al., 2023), we expected participants to report 10 days of alcohol and cannabis use on average across the 32 days of participation. Second, we had to make assumptions regarding the uncertainty surrounding multiple model parameters

[4]We collected data from 505 participants. 9 participants were excluded from the sample as they were identified to be ineligible during data cleaning.

(random intercept, random slopes, error term). We based these values on our previous work predicting substance use in EMA data. Based on these assumptions we simulated 1,000 datasets, fit our model in each of them, and counted the number of datasets in which the conditional effect of affect is significant, which represents the statistical power we have to detect this effect. These simulations indicate that we have 96% power to detect an effect as small as a rate ratio of 1.05, which indicates that a participant is estimated to consume an additional 0.05 drinks as affect increases by one standard deviation. The code for the power simulations can be found at https://osf.io/fm6cq/.

Participants were recruited for participation in a larger study on the development of alcohol and cannabis use problems during young adulthood. Participants were young adults (n = 496, aged 18 – 22, 55.8% assigned female sex at birth) and were recruited from King, Pierce, and Snohomish Counties from both college and non-college sources. Recruitment began in August of 2020 and was completed in November of 2022. Participants were required to be between the ages of 18 and 22 at study screening, own a smartphone, be fluent in English, and report drinking alcohol *or* using cannabis at least 'about once per week' over the past three months. The sample was stratified along sex and age (we attempted to recruit equal number of male and female participants at each age). Participants were excluded if they were not fluent in English or if they moved to the United States after age 12, to screen out participants who were not acculturated to United States norms of substance use. We used several recruitment methods (e.g., social media ads, university registrar lists and high-school list-servs, newspaper ads, flyers) and sampled from a wide variety of neighborhoods with differential aggregate socioeconomic status (as indicated by the 2020 census) to achieve a diverse sample in terms of gender identity and race/ethnicity. Thus, while our sample is not a representative one, it can be considered a high-risk community sample broadly reflecting Washington census data from counties in which participants were recruited. We achieved this aim in terms of gender identity (47.2% cisgender female, 43.8% cisgender male, 12.9% nonbinary/genderqueer/gender non-conforming, 4.0% transgender male or female, 0.06% non-gendered) and race/ethnicity (69.6% non-Hispanic White, 26.2% Asian, 6.7% African American, 8.5% Hispanic/Latino, and 9.9% who endorsed more than one ethnicity)[5]. Participants completed a total of 104 EMAs on average, with a completion rate of 62%.

Analysis Plan

We conducted all analyses in R (R Core Team, 2021) using the glmmTMB (Brooks et al., 2017), dplyr (Wickham et al., 2019), and mice (van Buuren & Groothuis-Oudshoorn, 2011) packages. First, we used multiple imputation to account for missing data. We imputed 5 datasets due to the high computational cost of our analyses. Continuous variables (e.g., affect) were imputed via mixed-effects predictive mean matching while zero-inflated count outcomes (i.e., alcohol use) were imputed via a mixed-effects Bayesian non-linear regression approach. The imputation algorithm (described in more detail below) imputed missing EMA data simultaneously from baseline and EMA data while taking the nested structure of the data (EMA data clustered in participants) into account (Dora et al., 2024).

[5]Participants were allowed to indicate more than one gender identity and race/ethnicity, which is why these numbers exceed 100%.

We included all relevant variables from the baseline and EMA that predicted missingness to meet the imputation assumptions of data missing at random.

Then, we fit four specification curves (Simonsohn et al., 2020) to test our four hypotheses, which comprise three steps: First, we identified many valid and justified ways in which the hypothesis can be translated into a statistical model. Second, we estimated these models, and performed an omnibus test that provided evidence for the degree of support for the hypothesis jointly across all model specifications. Third, we then compared results across specifications to determine which specifications (if any) influenced the conclusions. As repeated measures (days) were nested in participants and alcohol and cannabis use are zero-inflated, we fit mixed-effects hurdle models. For alcohol use, we followed our preregistered analysis plan, using a negative binomial distribution for the non-zero counts. For cannabis use, we deviated from our preregistration by implementing a hurdle Gamma model, as cannabis use was reported in grams (which we did not realize a priori) rather than counts, making the Gamma distribution more appropriate for modeling the non-zero values. The models followed the general form of a hurdle model with the following specifications:

For modeling the likelihood of use[6]:

$$\text{logit}\left(P\left(Y_{ij} = 0\right)\right) = \beta_{0_i} + \beta_1 Affect_{ij} + \beta_2 Moderator + \beta_3\left(Affect_{ij} \times Moderator\right)$$

For modeling the quantity given use:

$$\log\left(E\left[Y_{ij} \mid Y_{ij} > 0\right]\right) = \gamma_{0_i} + \gamma_1 Affect_{ij} + \gamma_2 Moderator + \gamma_3\left(Affect_{ij} \times Moderator\right)$$

Where Y_{ij} represents the alcohol/cannabis use quantity for person i on day j.

Thus, both models separately predicted whether participants reported use (likelihood) and the quantity on use days. Each model included a fixed intercept, fixed effects for our predictor(s), and a random intercept to account for between-subjects variation in alcohol and cannabis use. We attempted to model random slopes for affect, but a significant portion of models including random slopes in the specification curve analyses did not converge. Therefore, in line with our preregistration, we simplified the model. To ensure that affective states temporally preceded substance use, affect reports collected during or after the onset of use were excluded from the analyses. This procedure ensured that the predictors reflected affective experiences occurring prior to substance use. For example, if a participant reported their first drink at 6 p.m., the daily average affect was computed using reports obtained up to 6 p.m., thereby maintaining clear temporal separation between predictors and outcomes. On non-use days, affect reports provided after the participant's median onset time of substance use (calculated from their use days) were omitted. We fit each model in each of five imputed datasets and then pooled the results, arriving at one estimate, confidence interval,

[6]The model predicts the likelihood of *not* using alcohol/cannabis that day. For ease of interpretation, we inverse this coefficient to represent the likelihood of using alcohol/cannabis in the remainder of the paper.

and *p*-value per model specification (van Buuren & Groothuis-Oudshoorn, 2011). Models differed along the following specifications:

- Different affect variables: Anger, sadness, anxiety, distress, and the average across the four states were used to represent negative affect. Joviality, attentiveness, serenity, and the average across the three states were used to represent positive affect. Affect variables were person-mean standardized so that they have a mean of 0 and a standard deviation of 1. This was done so that the affect parameter can be interpreted as a change in substance use as affect increases relative to the participant's own mean (i.e., reflect a within-person process), which is what we were interested in testing here. This specification informed whether specific affective states differentially predict substance use. The choice for these states and items was made to be able to model the affective experience as broadly as possible while minimizing EMA survey length.
- Different operationalizations of time scale: We computed the daily mean of affect reported prior to substance use, the daily maximum of affect reported prior to substance use, the daily most recent affect reported prior to substance use, the daily variability of affect (operationalized as the standard deviation of the affect items across EMA surveys) reported prior to substance use, and the daily emotion differentiation (operationalized as the index derived from the intraclass correlation coefficient by Erbas et al., 2022) prior to substance use.
- Different moderators - alcohol: No moderator, AUD criterion count calculated from AUDDCSI (Boness et al., 2019), AUD symptom count calculated from AUDDCSI, Alcohol Use Disorder Identification Test score (Saunders et al., 1993), coping (in NA models) and enhancement motives (in PA models) (Cooper, 1994) (± 1 standard deviation due to a lack of established cutoff scores), and social context (alone vs others).

To compare effect sizes of interaction models with main effects models including no interaction, we estimated a conditional effect of negative affect on alcohol use for participants at two values for each moderator rather than interpreting the interaction term, as has been recommended for interactions in nonlinear models (Kim & McCabe, 2022; McCabe et al., 2022; Rohrer & Arslan, 2021). We tested the effect at AUD criterion counts of 2 (mild AUD according to DSM-5) and 6 (severe AUD according to DSM-5), AUD symptom counts of 2 and 12 (these are the values matching closest the mild and severe AUD diagnosis), AUDIT scores of 3 (median score in our pilot datasets) and 8 (established AUD cutoff score), drinking motives one standard deviation above and below the sample mean (due to a lack of established cutoff scores), and on days participants were alone versus with others. This specification informed whether associations between affect and alcohol use differ for people with varying AUDDCSI, AUDIT, and DMQ scores, and on days where participants were alone versus with others.

- Different moderators - cannabis: No moderator, Cannabis Use Disorder Identification Test-Revised score (Adamson et al., 2010) (3 = expected median score and 13 = established CUD cutoff score), coping and enhancement motives

(Simons et al., 1998)(± 1 standard deviation due to a lack of established cutoff scores), and social context (alone vs others). Same reasoning as above.

- Controlling for covariates: Our preregistration specified the following covariates: sex assigned at birth, simultaneous cannabis use (in alcohol models), simultaneous alcohol use (in cannabis models), mean positive affect (in NA models), mean negative affect (in PA models), day of the week, season (spring, summer, fall, winter). We chose these six covariates as they are commonly statistically controlled for in this literature. While we initially planned to examine all possible additions of these covariates in our specification curves (which would have resulted in as many as 1,650 specifications in a single curve), this approach created excessive computational demands on our computing cluster (i.e., exceeding the one-month maximum timeframe for computation on the cluster per permutation test). Therefore, we deviated from our preregistration by simplifying to just two covariate approaches: either including all covariates simultaneously or including no covariates.

The above combinations resulted in 500 (negative affect) and 400 (positive affect) model specifications for alcohol use and 300 (negative affect) and 240 (positive affect) model specifications for cannabis use[7]. We calculated and report the median effect size across all specifications and the proportion of specifications that resulted in a significant effect ($\alpha = .05$). The resulting graph enabled us to explore to what extent different specifications are consequential to the conclusions (Simonsohn et al., 2020). Then, for alcohol use, we performed a joint permutation inference to test whether our results across all specifications are inconsistent with the null hypothesis. For this, we initially planned to create 500 datasets in which we randomly shuffle the substance use variables between days (but within participants, to account for the nested structure of the data). Due to computational demands, we had to reduce this to 125 shuffled datasets. This allowed us to create a distribution of specification curves under the null hypothesis (which we 'forced' via the shuffling) and perform an inferential test by calculating the proportion of shuffled datasets in which we observe more significant specifications than in the original dataset. The number of shuffled datasets in which more specifications are significant than in the original datasets divided by the total number of shuffles equals the *p*-value associated with this test (Simonsohn et al., 2020). Thus, the omnibus null hypothesis is rejected if there are more effects that are significant in fewer than 5% of the shuffled datasets. We did not perform such a permutation test for cannabis use given the lack of statistically significant specifications (rendering the conclusion obvious) and the computational demands of this analysis.

In our primary analyses, we separately modeled the associations of negative and positive emotions with substance use. We do this as most theoretical models relating to affect regulation of substance use discuss separately the motivating forces of negative and positive emotions (e.g., Baker et al., 2004; Koob & Le Moal, 2008). In our meta-analysis of the

[7]Two things are important to acknowledge. First, it is impossible to capture all meaningful specifications along which affect regulation theory could be tested. Second, these specification curves of mixed-effects mixture models in multiple imputed datasets have a high computational cost (our pilot analyses ran for ~ 4 weeks on a supercomputing cluster). For these two reasons, we attempted to identify the specifications most relevant to testing the theory of affect regulation in everyday life.

affect-alcohol use EMA literature, negative and positive affect were weakly negatively correlated at the within-person level ($r = -.09$; Dora et al., 2023). Some research has suggested that, depending on the situation, negative and positive emotions can be uncorrelated, strongly negatively correlated, and even positively correlated (Rafaeli et al., 2007). For example, many people feel both happy and sad on the day they graduate from college (Larsen et al., 2001). One study found that when affect is highly polarized (i.e., reports of negative and positive emotions are strongly negatively correlated), people are more prone to use substances (Coifman et al., 2012). As a sensitivity analysis we generated one additional specification curve for alcohol use and one for cannabis use where the single affect specification is affective synchrony (the daily correlation between negative and positive affect). This analysis can tell us whether people use more alcohol and cannabis on days their affect is more polarized.

Our preregistration, data, and analysis code can be found at https://osf.io/fm6cq/.

Results

Multiple imputation

Missing data were handled using multiple imputation with the mice package in R (van Buuren & Groothuis-Oudshoorn, 2011). We generated 5 imputed datasets with 50 iterations each. For baseline variables, we used predictive mean matching, while for time-varying EMA measures we employed a two-level imputation approach to account for the nested structure of the data (observations nested within participants). Specifically, we used two-level predictive mean matching for visual analog scale items and cannabis use, and two-level negative binomial regression for alcohol use. Scales (positive and negative affect) and interaction terms were handled through passive imputation, where they were computed as derived variables from their constituent items. The imputation model included all analysis variables as predictors. Convergence and fit of the imputation model was evaluated by inspecting R-hat values, inspecting trace plots, and comparing the distributions of observed and imputed values across datasets. Figure 1 shows density plots for key variables (alcohol and cannabis use quantities, discrete emotion items ‘unhappy’ and ‘excited’, and composite negative and positive affect scales), demonstrating consistent distributions across imputations.

Descriptive statistics

Participants reported consuming alcohol on 31.7% of days and cannabis on 29.9% of days. On days they reported use, they reported consuming an average of 4.08 alcoholic drinks (SD=3.56, *range*=1–30) and 2.13 grams of cannabis (SD=2.92, *range*=0.02–21.96). Across all days, participants reported consuming alcohol in a social setting (vs. alone) on 76.1% of days, and cannabis on 75.5% of days. The average reported daily negative affect was 9.05 (SD=12.51, *range*=0–93.31) and positive affect was 43.19 (SD=21.96, *range*=0–100).

Participants had an average AUDIT score of 7.66 (SD=5.48, *range*=0–37), with 198 participants (39.9%) of the sample having a score of 8 or higher. Based on the AUDDCSI, responses indicated that of the total sample, 196 participants (39.5%) endorsed no AUD criteria, while 101 (20.4%) endorsed one criterion. Among those meeting the minimum threshold for AUD diagnosis (≥2 criteria; n=199, 40.1%), severity was distributed as follows: 107 participants (21.6%) met criteria for mild AUD (2–3 criteria), 73 (14.7%) for moderate AUD (4–5 criteria), and 19 (3.8%) for severe AUD (6–11 criteria). The average CUDIT score was 7.44 (*SD*=6.68, *range*=0–30). The average coping motives for alcohol use and cannabis use were 2.13 (*SD*=1.06, *range*=1–5) and 2.12 (*SD*=1.16, *range*=1–5) respectively. The average enhancement motives for alcohol use and cannabis use were 3.07 (*SD*=1.13, *range*=1–5) and 3.19 (*SD*=1.41, *range*=1–5) respectively. Between-person correlations among study variables are shown in Figure 2.

Specification Curves

Table 2 summarizes our four specification curve analyses. Before presenting specific findings, we note that interpretation of SCAs differs from conventional hypothesis testing. The permutation tests provide our primary inferential tool for determining whether an overall pattern of results is inconsistent with the null hypothesis. When permutation tests are significant, this indicates the observed pattern of results (including both significant and non-significant specifications) would be unlikely to occur by chance. The proportion of significant specifications provides insight into the robustness of an effect across different analytical decisions, not a threshold for determining if an effect exists. For example, even when fewer than half of specifications are significant, the pattern may still be robust if the permutation test confirms that we would almost never observe this many significant specifications under the underlying null hypothesis.

To examine consistency across moderators and other specifications, we visually assessed the distribution of significant specifications across different analytical choices. When significant results appear relatively evenly distributed across levels of a moderator, we concluded the effect is consistent across those moderator levels, even if the effect is not significant in all specifications. It’s important to note that this assessment is qualitative and based on judgment, not a formal statistical test. We therefore encourage readers to study the right side of Figures 2–5 and draw their own conclusions.

Negative affect predicting alcohol use

These specification curves are visualized in Figure 3. For the likelihood to drink alcohol, 103 (20.60%) of the 500 specifications yielded statistically significant effects ($p < .05$). The median effect size across all specifications (*OR* = 0.95) indicates a 5% *decreased* likelihood to drink as negative affect increases by one standard deviation. A permutation test using 125 shuffled datasets indicated this pattern of results was significantly different from what would be expected by chance ($p < .001$), suggesting robust evidence that negative affect is associated with a slightly decreased likelihood to drink.

This association showed marked differences across affect operationalization and time scales. The type of negative affect mattered substantially: for example, sadness showed more consistent negative associations with drinking likelihood (40% significant specifications) compared to anger (0% significant specifications). Maximum negative affect reported during the day was a stronger predictor of reduced drinking likelihood compared to most recent negative affect, with 37% vs 15% of specifications reaching significance respectively. Contrary to theoretical predictions, there were subtle differences across moderator levels, with the negative association being slightly more pronounced among those with higher coping motives (20% significant specifications) compared to those with lower coping motives (0%), and somewhat stronger at lower AUD criteria levels (AUD=2; 25% significant) than at higher levels (AUD=6; 15% significant). While these differences across moderator levels are not substantial, they run counter to the direction predicted by affect regulation theories, which would expect stronger positive associations between negative affect and drinking for those with higher coping motives and more severe AUD symptoms.

For the quantity of alcohol consumed on drinking days, only 21 (4.2%) of the 500 specifications yielded significant effects. The median IRR of 1.00 suggests minimal impact of negative affect on drinking quantity. The permutation test did not indicate these results were significantly different from chance ($p = .104$).

Positive affect predicting alcohol use

These specification curves are visualized in Figure 4. For the likelihood to drink alcohol, 184 (46.00%) of the 400 specifications yielded statistically significant effects. The median odds ratio was 1.05, suggesting a small increased likelihood to drink with higher positive affect when averaged across all specifications ($p < .001$).

However, this median effect masks important differences across affect operationalizations. High-arousal positive affects like joviality showed consistent stronger positive associations with drinking likelihood (median OR = 1.15, 58% significant specifications), while low-arousal positive affects like serenity and attentiveness showed weaker effects (median OR = 1.04, 34% significant specifications). These patterns were there when studying the mean, most recent, and maximum positive affect (but not the variability in positive affect or differentiation) and robust across different moderators and covariate specifications.

For quantity consumed on drinking days, 58 (14.50%) of specifications were significant, split between positive (41 specifications, 10.25%) and negative effects (17 specifications, 4.25%). The median IRR was 1.05. While the overall permutation test was significant ($p < .001$), only the directional test for positive effects was significant ($p < .001$), but the test for negative effects was not ($p = .136$).

Negative affect predicting cannabis use

These specification curves are visualized in Figure 5. None of the 300 specifications examining negative affect's association with cannabis use likelihood showed significant effects. The median odds ratio was 1.00, suggesting no meaningful association. Similarly, when predicting quantity of cannabis used, none of the 300 specifications yielded significant results, with a median regression coefficient of −0.01. Given the complete absence of significant specifications, permutation tests were not conducted as the results clearly indicate no evidence for an association between negative affect and cannabis use.

Positive affect predicting cannabis use

These specification curves are visualized in Figure 6. Only 3 (1.25%) of 240 specifications showed significant associations between positive affect and likelihood of cannabis use, with a median odds ratio of 1.02. For cannabis quantity, just 1 specification (0.04%) yielded a significant result, with a median regression coefficient of 0.00. As with negative affect, permutation tests were not conducted given the clear lack of evidence for any association between positive affect and cannabis use.

Affect synchrony predicting alcohol and cannabis use

These specification curves are visualized in Figures S1 and S2. Across moderators and covariates, affect synchrony (the daily correlation between negative and positive affect) consistently was not associated with either alcohol use or cannabis use.

Discussion

Using specification curve analyses across hundreds of model specifications, we found complex and sometimes unexpected associations regarding affect regulation models of alcohol and cannabis use (Baker et al., 2004; Cox & Klinger, 1988; Koob & Le Moal, 2008) in daily life. Our comprehensive approach directly addresses key untested aspects of our previous meta-analysis (Dora, Piccirillo, et al., 2023), which found no evidence for the general hypothesis that negative affect predicts same-day alcohol use at the within-person level. That work primarily tested whether mean negative affect throughout the day predicted subsequent drinking in a variety of populations, leaving open the possibility that different operationalizations of negative affect, alternative time scales, or specific populations might show the hypothesized associations. The present study tested these alternative possibilities across a wide range of specifications, yet the results were unambiguous: For alcohol use, higher negative affect predicted a modest decreased likelihood of drinking, while positive affect consistently predicted increased likelihood of drinking, with high-arousal states showing stronger and more consistent effects than low-arousal states. These patterns were consistent across substance use disorder severity and social contexts, though importantly, we found that higher coping motives and AUD criteria count paradoxically somewhat strengthened the negative relationship between negative affect and drinking likelihood, contrary to theoretical predictions. In contrast, neither negative nor positive affect predicted any aspect of cannabis use across any model specification. These findings challenge several core assumptions of affect regulation models of substance use and suggest the need for theoretical refinement.

The finding that negative affect predicts a slightly decreased likelihood of drinking (with a median odds ratio of 0.95) but not drinking quantity aligns well with our recent meta-analysis (Dora, Piccirillo, et al., 2023). The current study extends this work by demonstrating the robustness of these associations across multiple theoretical and methodological specifications. In people's daily lives (particularly young adults), days and moments characterized by higher negative affect are *less* likely to be followed by alcohol use, not more. Negative affect was not associated with an increase in alcohol use regardless of which discrete negative emotion was examined, though the strength of this relationship varied by emotion type and time scale. The association was more evident when examining certain negative emotions like sadness (40% significant specifications) compared to others such as anger (0% significant specifications). Counterintuitively, negative affect more consistently predicted decreased likelihood to drink among participants reporting high coping motives compared to those reporting low coping motives, and this pattern was somewhat stronger at lower AUD symptom levels. While these moderation effects were modest, they directly contradict affect regulation models which would predict stronger *positive* associations between negative affect and drinking for those with higher coping motives and more severe AUD symptoms. This comprehensive examination suggests that the inverse association between negative affect and drinking is not an artifact of measurement decisions or analytical choices, but rather represents a robust pattern that demands theoretical attention and reconsideration.

The arousal-dependent association we found between positive affect and drinking likelihood adds important nuance to our meta-analytic finding that positive affect generally predicts increased drinking (Dora, Piccirillo, et al., 2023). Both high and low-arousal positive states predicted increased likelihood of drinking, but with notable differences in magnitude and consistency. High-arousal states like joviality showed stronger and more consistent positive associations with drinking likelihood (median OR = 1.15, 58% significant specifications), while low-arousal states like serenity showed weaker, though still positive, associations (median OR = 1.04, 34% significant specifications). This arousal-dependent pattern may explain why previous EMA studies (e.g., Dvorak et al., 2014; N. N. Emery et al., 2023; Litt et al., 2023), which predominantly relied on the PANAS (Watson et al., 1988) with its focus on high-arousal emotional states, have not detected these varying effects.

The positive association between high-arousal states and drinking was strongest when examining mean, most recent, and maximum daily joviality prior to drinking onset, suggesting that both sustained and immediate positive excitement may precede drinking episodes. It is important to point out that this association need not be causal; in a recent project, we found some evidence that positive affect might rise in anticipation of a drinking episode (King et al., 2025). These positive affect associations were generally consistent across alcohol use disorder severity, enhancement motives, and social context, supporting the idea that positive affect's relationship with drinking behavior represents a fundamental pattern regardless of problem severity or drinking situation.

In marked contrast to alcohol use, we found no evidence that either negative or positive affect predicted cannabis use across any of our model specifications. This comprehensive null finding - observed across different discrete emotions, time scales, and moderators including cannabis use disorder severity and motives - is particularly surprising given it diverges sharply from our previous specification curve analysis of 287 regularly using college students, where we found robust evidence that negative affect predicted decreased likelihood of cannabis use, while positive affect predicted increased likelihood of use (Dora, Smith, et al., 2023; but see also Testa et al., 2019; Wycoff et al., 2018). In the present study, we also found null associations between affect and the quantity of cannabis use.

The stark difference in findings between our prior SCA study and this one defies straightforward explanation. We examined several potential factors that might explain these differences, but none proved satisfactory. The studies are comparable in terms of cannabis use frequency, sampling approaches, and were collected only a few years apart (though perhaps cannabis use trends are changing in Washington State, where the data were collected). Despite examining a wide range of potential moderating variables including cannabis use disorder symptoms, use patterns, motives, and social context, none of the variables we measured could account for the divergent results. While the current sample was larger and included both college and non-college young adults, the basic demographics and study designs were similar across both studies. This unexplained discrepancy highlights the complexity of studying affect-substance use associations and calls for innovative research approaches to uncover what factors might drive such different patterns of results across studies.

Overall, our findings in this line of research present a theoretical paradox: people report using substances to cope with emotions, coping motives are clearly a meaningful signal as they predict use frequency and substance-related problems (Bresin & Mekawi, 2021; Hammarberg et al., 2017), yet daily affect does not predict use, not even among those with high coping motives. Two broad classes of explanation could resolve this paradox.

First, people high in negative emotionality may tend to attribute their use to emotional factors post-hoc, as individual differences in coping motives are associated with both negative emotionality and with alcohol and cannabis use (Moss et al., 2025). Alternatively, coping motives may capture expectancies about mood effects rather than actual experiences of affect regulation (Kuntsche et al., 2007; Schultz et al., 2024). These explanations would imply that coping motives do not accurately reflect what is happening in people's daily lives, but instead reflect people's *beliefs* about how substances affect them. Second, affect regulation may genuinely occur (at least for people high in coping motives) but our current methods fail to capture it. EMA studies like ours cannot reliably capture immediate precipitants in the minutes before deciding to use and do not identify highly specific contexts where regulation may occur (e.g., when substances are immediately available with no constraints). EMA studies cannot identify rare but clinically potentially important episodes, or regulation occurring at different time scales than we measure. All this is to say, at this point we cannot be certain what these patterns in our data mean, but we are certain that they are robust. Moreover, we believe that is imperative for the field to grapple with the reality of the data and work to refine and revise theory, rather than continue to hunt for affirmative and ignore disconfirming evidence when it comes to within-person associations between emotional states and substance use.

Resolving this paradox is not easy to do but critical for our understanding of the etiology of substance use disorders. If coping motives reflect beliefs, it might be possible to influence them by experimentally manipulating alcohol expectancies. If affect regulation occurs in specific unmeasured contexts, innovative EMA designs capable of capturing and identifying such episodes at finer temporal resolution are necessary. Additional data will be needed to disentangle these potential explanations.

Our findings raise important questions about the discrepancy between laboratory studies and real-world EMA research on affect-substance use associations. Various experimental paradigms in the laboratory have indicated that inductions of negative mood or stress can lead to momentary increases in alcohol use (*Cohen's* D_{Avg} = .31; Bresin et al., 2018), yet there is no evidence for this association in daily life. This is true even when examining affect patterns that most closely resemble laboratory paradigms, such as the most recent negative affect reported before drinking onset. This represents a striking disconnect between laboratory findings and real-world contexts, highlighting a fundamental challenge for translating experimental research to everyday behavior. One possibility is that laboratory studies do not generalize to daily life. Laboratory studies create artificial scenarios where alcohol is immediately available following emotional manipulations, with minimal barriers to consumption and few consequences (these conditions are rarely met in everyday life). Additionally, anticipatory processes that occur in naturalistic settings (King et al., 2025) may be absent in laboratory contexts. One alternative explanation, discussed above, for this discrepancy might be that people's beliefs about alcohol's emotional effects, rather than their actual emotional states, drive drinking decisions. Recent experimental work supports this possibility. In an alcohol administration design, coping motives predicted greater *perceived* relief from negative affect after drinking but did not predict any actual reductions in negative affect, underscoring the disconnect between subjective impressions and real emotional outcomes (Echeverri et al., 2025).

Such findings highlight how expectations about emotion change, rather than actual emotional experiences, may drive drinking behavior and could explain why people emphasize affect regulation for their drinking in treatment settings. Cultural narratives and post-hoc reasoning may reinforce beliefs that negative emotions drive drinking, even when actual moment-to-moment behavior follows different patterns. As a consequence, EMA studies fail to find compelling evidence that negative affect predicts alcohol use in daily life. An alternative is that laboratory studies may capture a specific, uncommon situation that rarely occurs in daily life but might be important for understanding particular high-risk drinking episodes (e.g., moments following an acute stressor where alcohol is readily available).

Recent experimental work has begun to address some of these limitations by testing whether stress increases alcohol consumption when participants must actively choose alcohol over appealing non-alcoholic alternatives (Dora et al., 2025). This approach captures a critical real-world complexity that EMA research ignores: people experiencing negative affect often have multiple regulatory options available, and choosing substance use means forgoing those alternatives. Indeed, people were more likely to choose alcohol over an alternative when stressed. This suggests that affect regulation through substance use may be a genuine phenomenon that occurs under specific boundary conditions that are systematically created in laboratory settings but occur inconsistently in daily life. This could explain why EMA studies consistently find null results despite laboratory evidence for the mechanism.

Our results once again provide robust evidence challenging core assumptions of affect regulation theories of substance use (Baker et al., 2004; Cox & Klinger, 1988; Koob & Le Moal, 2008), at least within young adults ranging from social users to those with mild/

moderate substance use disorders. The findings directly contradict the premise that negative affect drives substance use through negative reinforcement, especially the theoretically critical prediction that this relationship would be stronger among individuals with higher coping motives. Our finding that the negative relationship between negative affect and drinking was actually stronger among those with higher coping motives and AUD criteria count represents a particularly puzzling contradiction to affect regulation theory. This aligns with recent EMA work in both clinical and young adult samples showing that positive reinforcement processes dominate negative reinforcement (King et al., 2025; Ringwald et al., 2025). The nuanced association between different types of positive affect and drinking - with high-arousal states like excitement showing stronger associations with increased use than low-arousal states like calmness - suggests that the motivational properties of positive affect may be tied to its arousal component, consistent with broader emotion research on how affective arousal influences judgment and decision-making (Blanchette & Richards, 2010). Our results suggest that, if negative emotional processes contribute to the development of substance use disorders, the pathway must operate differently than current theories propose - perhaps through emotional expectancies rather than current emotional states (Schultz et al., 2024), highly specific context-dependent effects, or mechanisms that only emerge in populations with more severe substance use disorders than those studied here (Walsh et al., 2023).

Constraints on generality

Our findings should be understood within specific constraints on their generality (Simons et al., 2017). Regarding participants, our results are based on young adults aged 18–22, with many meeting criteria for mild (2–3 criteria) or moderate (4–5 criteria) AUD or CUD but relatively few meeting criteria for severe AUD or CUD. While our sample included participants with a range of substance use patterns and problems (including 40.1% meeting the minimum threshold for AUD diagnosis), we cannot claim our findings generalize to older adults or those with more severe substance use disorders without further evidence. For temporal context, our weekend-focused sampling schedule (Thursday-Sunday) primarily captured patterns during days when substance use is most common, and may not represent patterns during weekdays (although a recent study in a large sample of adolescents and adults with a broader sampling schedule also found null results, see Litt et al., 2023). However, our previous meta-analysis of 350,000 participant-days from 69 studies, most of which sampled all seven weekdays, found identical within-person associations between affect and alcohol use (Dora, Piccirillo, et al., 2023), suggesting our findings likely generalize across the full week. Regarding measurement context, our design captured when substance use began but not the decision-making process leading to use, which creates some temporal ambiguity in affect-substance use associations (Dora et al., 2025). This is particularly important since anticipatory processes may influence both affect and substance use decisions (King et al., 2025). Additionally, while we observed both use and non-use days, we lack information about why participants did not use substances on non-use days (e.g., lack of desire versus lack of opportunity), which could be relevant for understanding affect regulation processes, particularly given evidence that negative affect reliably predicts substance use cravings (Leenaerts et al., 2025; Waddell et al., 2022) even though it predicts decreased likelihood of actual use. Additionally, individuals vary in their ability to accurately identify and differentiate emotional experiences (Barrett et al., 2001; Erbas et al., 2022), which could introduce heterogeneity in how affect relates to substance use.

Our findings point to several testable hypotheses about when affect regulation might influence substance use in ways consistent with theoretical predictions, if ever. If negative reinforcement processes emerge primarily at higher levels of clinical severity, we would expect to observe positive associations between negative affect and substance use specifically in individuals with advanced AUD who are seeking treatment, but not in community samples. Developmental timing may also be crucial; these processes might only become evident later in life, when substance use patterns have become more entrenched and less socially determined. The discrepancy between laboratory findings and naturalistic observations suggests that negative affect may drive substance use only under specific contextual conditions: when substances are immediately available, when social constraints are minimal, and when current and future responsibilities are not threatened. This would explain why negative affect predicts craving but decreased likelihood of actual use in daily life (Leenaerts et al., 2025; Waddell et al., 2022).

Conclusions

In summary, our comprehensive examination of daily within-person affect-substance use associations provides definitive evidence challenging fundamental assumptions about affect regulation and substance use in young adults. By testing hundreds of model specifications, we demonstrate a remarkably consistent pattern: negative affect never predicted increased likelihood of drinking across any specification. Instead, when significant associations were found (in about 20% of specifications), they were invariably negative, indicating decreased likelihood of drinking with higher negative affect. This negative association was slightly more pronounced for sadness, maximum daily affect, and surprisingly among those with higher coping motives and AUD criteria counts. The complete absence of affect-cannabis use associations and the arousal-dependent gradient of positive affect effects on drinking highlight the need for more sophisticated theories about how emotions influence substance use decisions. While these findings do not falsify affect regulation theory outright, they suggest the theory requires considerable refinement to specify when, for whom, and under what circumstances these processes operate. Understanding these boundary conditions will be essential for developing more effective interventions targeting the complex relationship between emotional states and substance use behavior.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability

All data and materials are available at https://osf.io/fm6cq/. Due to file size constraints, we share the specification curve model outputs on OSF but not the permutation test outputs, which exceeded storage limits and were processed only on our supercomputing cluster.

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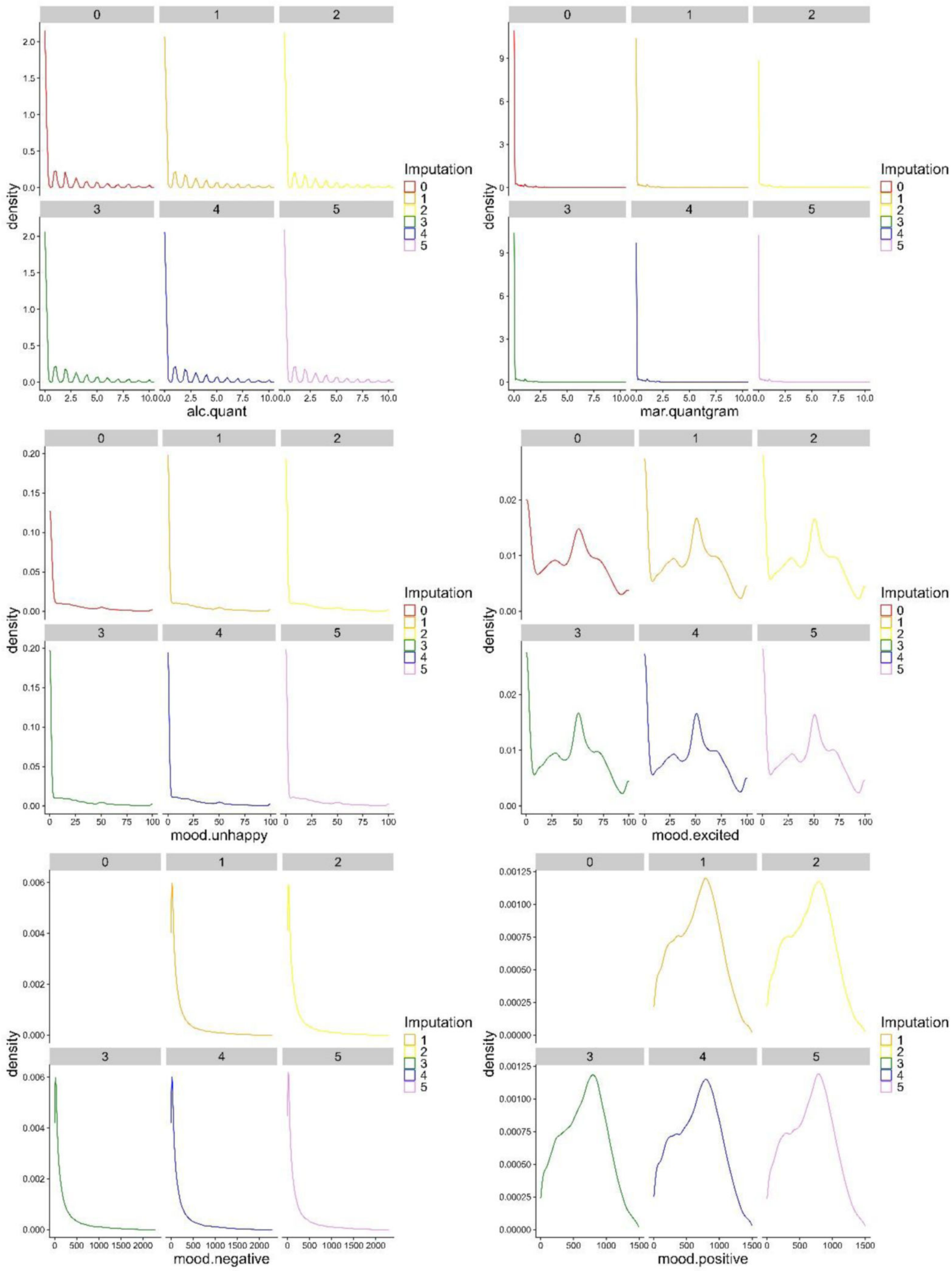

Figure 1.

Density plots comparing the distributions of key variables across the original and five imputed datasets. The figure shows the distribution of alcohol use (drinks), cannabis use (grams), discrete emotion items (‘unhappy’ and ‘excited’), and composite positive and negative affect scales across the original data and five imputations. The overlapping distributions indicate consistent imputation results across the multiply imputed datasets.

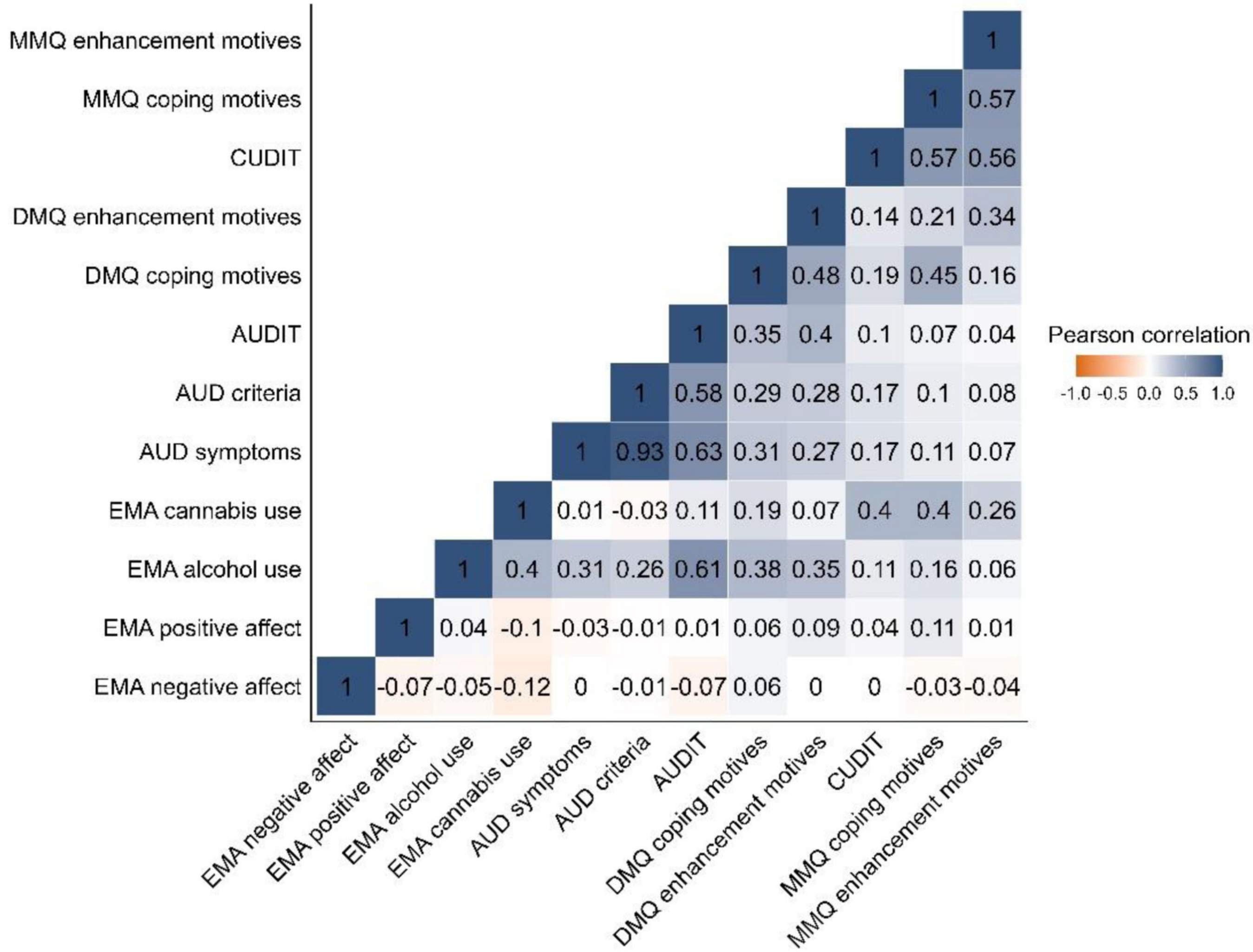

Figure 2.

Heat map of correlations between participant-aggregated affect, participant-aggregated substance use, and baseline study variables. The values in each tile represent the respective Pearson’s correlation coefficient. The magnitude and direction of correlations are visualized with colors.

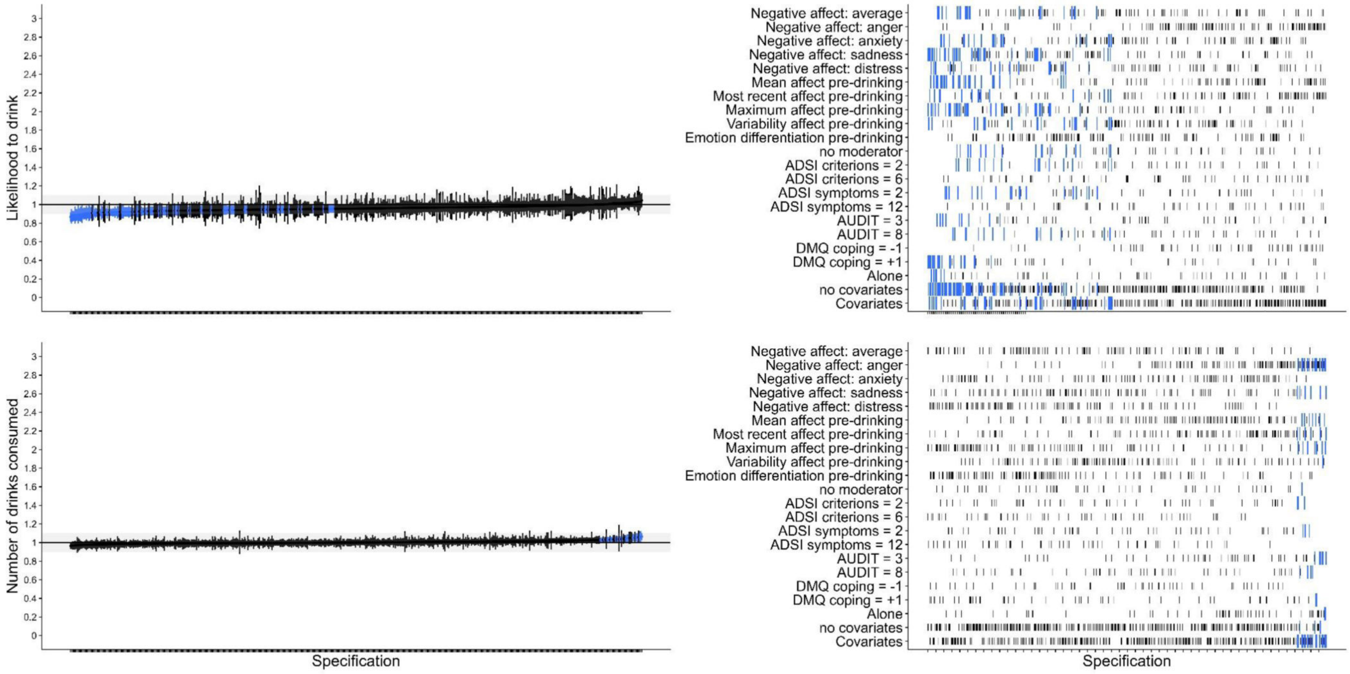

Figure 3.

Results of Specification Curve Analyses for negative affect predicting likelihood to drink (top) and number of drinks consumed (bottom). The top panel shows odds ratios (OR), where 1.0 indicates no effect, values below 1.0 indicate decreased likelihood, and values above 1.0 indicate increased likelihood. The bottom panel shows incidence rate ratios (IRR), where 1.0 indicates no effect on quantity consumed. Gray bars indicate the range of equivalence. Specifications in blue are those for which negative affect was a statistically significant predictor. Tick marks in the rightmost panels indicate, for each row, whether that variable was present or absent from the specification.

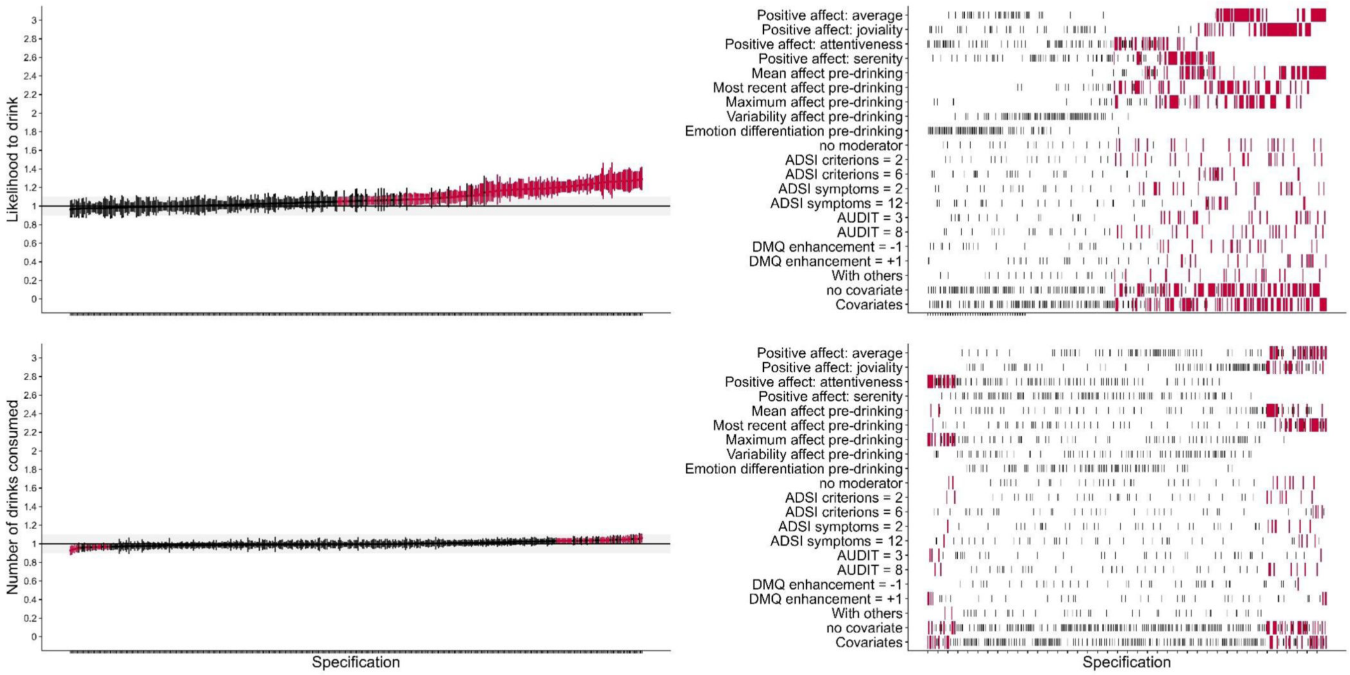

Figure 4.

Results of Specification Curve Analyses for positive affect predicting likelihood to drink (top) and number of drinks consumed (bottom). Specifications in red are those for which positive affect was a statistically significant predictor. Tick marks in the rightmost panels indicate, for each row, whether that variable was present or absent from the specification.

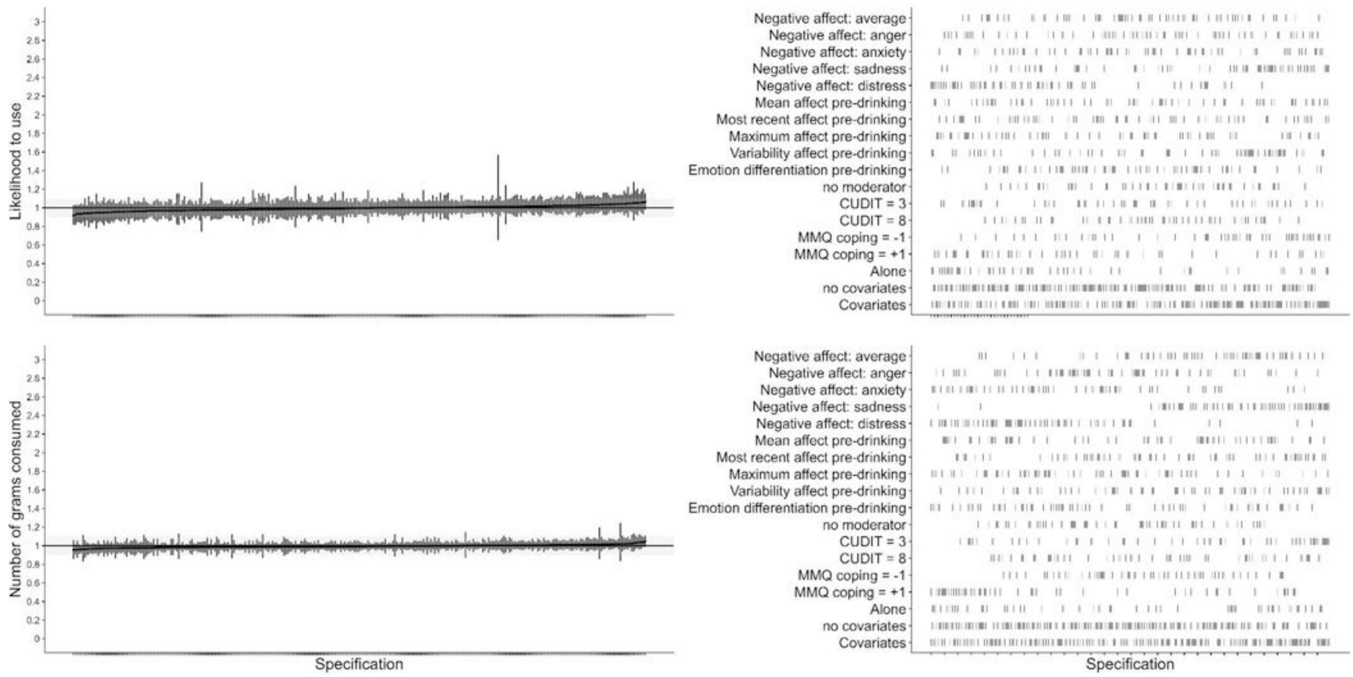

Figure 5.

Results of Specification Curve Analyses for negative affect predicting likelihood to use cannabis (top) and grams of cannabis consumed (bottom). None of the specifications resulted in statistically significant prediction. Tick marks in the rightmost panels indicate, for each row, whether that variable was present or absent from the specification.

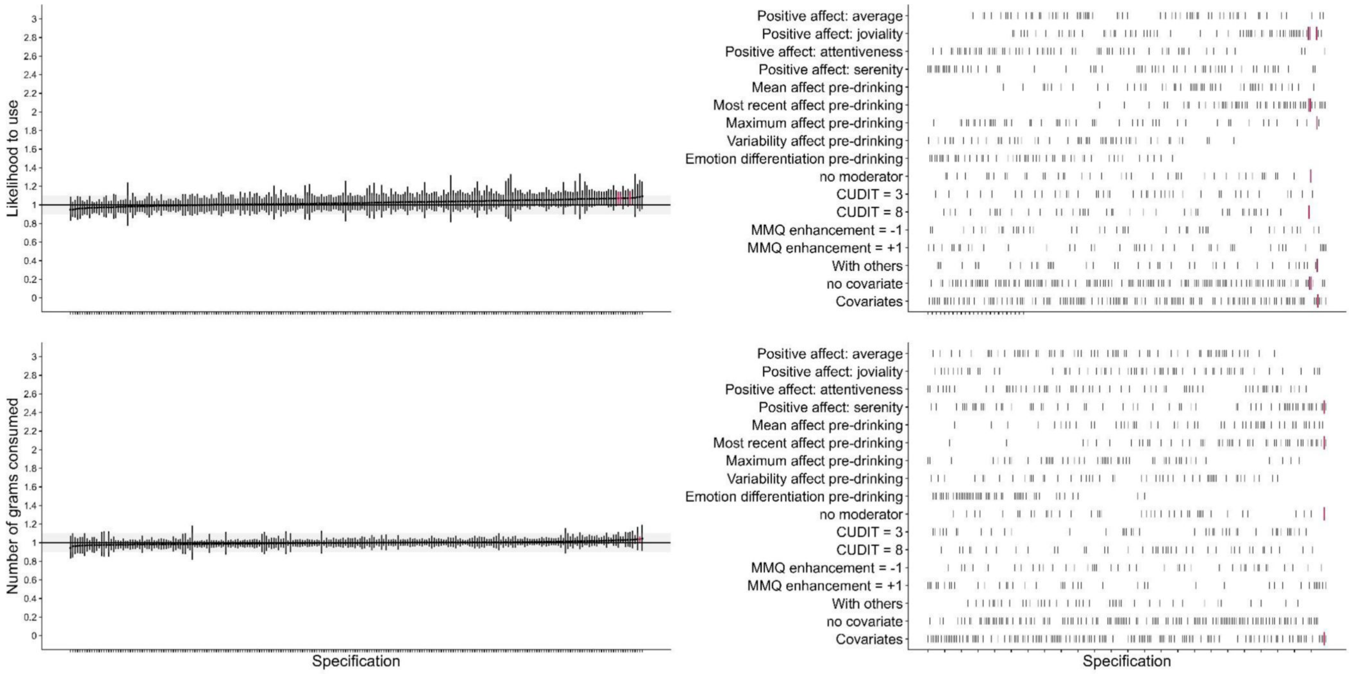

Figure 6.

Results of Specification Curve Analyses for positive affect predicting likelihood to use cannabis (top) and grams of cannabis consumed (bottom). Specifications in red are those for which positive affect was a statistically significant predictor. Tick marks in the rightmost panels indicate, for each row, whether that variable was present or absent from the specification.

Table 1.

Negative and positive affective states and items.

Negative affect				Positive affect		
Anger	**Sadness**	**Anxiety**	**Distress**	**Joviality**	**Attentiveness**	**Serenity**
Angry	Unhappy	Anxious	Upset	Happy	Alert	Calm
Irritated	Sad	Afraid	Distressed	Cheerful	Attentive	Relaxed
Hostile	Blue	Nervous	Guilty	Delighted	Determined	At ease
Annoyed	Alone	Jittery	Ashamed	Joyful	Concentrating	
Scornful	Lonely	Shaky		Enthusiastic		
Disgusted	Downhearted	Frightened		Energetic		
Loathing		Scared		Lively		
				Excited		

Table 2. Results of specification curve analyses.

The relevant effect sizes for likelihood of alcohol and cannabis use are odds ratios and for the number of drinks consumed incidence rate ratios. For these effect sizes, a value of 1.0 reflects the absence of an effect.

	Results of specification curve in our dataset			Permutation test
Hypothesis	***N* of specifications**	**Median effect size**	***N* of significant specifications (%)**	***N* of 125 shuffled datasets with more significant specifications than in the original dataset (*p*)**
Negative affect → likelihood of drinking alcohol	500	0.95	103 (20.60)	0 (<.001)
Negative affect → number of alcoholic drinks	500	1.00	21 (4.2)	13 (.104)
Positive affect → likelihood of drinking alcohol	400	1.05	184 (46.00)	0 (<.001)
Positive affect → number of alcoholic drinks	400	1.00	58 (14.50) 41 (10.25) 17 (4.25)	Overall: 0 (<.001) Positive: 0 (<.001) Negative: 17 (.136)
Negative affect → likelihood of using cannabis	300	1.00	0 (0.00)	Not performed
Negative affect → grams of cannabis	300	−0.01	0 (0.00)	Not performed
Positive affect → likelihood of using cannabis	240	1.02	3 (1.25)	Not performed
Positive affect → grams of cannabis	240	0.00	1 (0.04)	Not performed