USING ECOLOGICAL MOMENTARY ASSESSMENT TO IDENTIFY RISK FACTORS FOR SIMULTANEOUS ALCOHOL AND CANNABIS USE

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Doctor of Philosophy

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

USING ECOLOGICAL MOMENTARY ASSESSMENT
TO IDENTIFY RISK FACTORS
FOR SIMULTANEOUS ALCOHOL AND CANNABIS USE

presented by Andrea M. Wycoff,

a candidate for the degree of doctor of philosophy,

and hereby certify that, in their opinion, it is worthy of acceptance.

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Professor Timothy J. Trull

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Professor Denis M. McCarthy

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Professor Phillip K. Wood

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Professor Mary Beth Miller

DEDICATION

To my parents, Don and Wei, who met while completing their PhDs in chemistry, letting me know this path was possible. They have supported me and cheered me on my whole life, graduate school being no exception.

To the lifelong friends that I made during graduate school. Together we have laughed, cried, celebrated, and commiserated. This degree would not be the same without all of them.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Abstract

Using alcohol and cannabis simultaneously, such that their effects overlap, is prevalent among individuals who drink alcohol and is associated with greater negative consequences than use of either substance alone. Understanding the factors that contribute to and maintain simultaneous versus single-substance use may shed light on reinforcement processes and intervention targets for this pattern of use. We used ecological momentary assessment to examine these processes in individuals' daily lives. The study had three aims: 1) test whether baseline motives for simultaneous use moderated daily-life associations between affect and simultaneous use, 2) test whether momentary motives for using alcohol or cannabis differed depending on whether individuals were simultaneously using the other substance, and 3) test whether simultaneous use moments were associated with greater affectively reinforcing outcomes compared to single-substance use. After completing baseline measures of motives for alcohol, cannabis, and simultaneous use, participants (N = 88, mean age 25.22, 60.2% female) reported 6+ times daily for 14 days on alcohol and cannabis use, affect, momentary motives for use, and subjective appraisals of use. Multilevel models were used to test each aim. Results from aim 1 include that baseline motives for simultaneous use did not moderate affect-use associations in daily life. Results from aim 2 demonstrated that social, conformity, and expansion motives were endorsed more strongly during simultaneous- compared to single-substance use moments. Results from aim 3 include that simultaneously using cannabis during alcohol-use moments attenuated the positive association between momentary anxiety-coping drinking motives and subjective drinking-contingent relief but also attenuated the *increase* in negative affect

that accompanied coping-motivated drinking. In addition, simultaneously using cannabis during alcohol-use moments attenuated the positive association between enhancement drinking motives and subjective drinking-contingent pleasure despite no attenuation of the increase in positive affect that accompanied enhancement-motivated drinking. Collectively, this study furthers our understanding of the experiences that individuals are hoping to achieve by using alcohol and cannabis simultaneously and highlights ways in which this pattern of substance use may be reinforced.

Keywords: alcohol, cannabis, marijuana, ecological momentary assessment, simultaneous use, motives, affect

Chapter 1. Introduction

Cannabis is the second most widely used substance among individuals who drink alcohol (second to tobacco; SAMHSA, 2013; Yurasek et al., 2017). Most individuals who use both alcohol and cannabis report using them simultaneously, such that their effects overlap, at least some of the time versus always using them separately (co-use; Subbaraman & Kerr, 2015). Compared not only to individuals who only use alcohol but also to individuals who co-use both substances separately, those who use them simultaneously report greater quantity and frequency of alcohol use, greater alcohol-related harms and negative social consequences, greater frequency of alcohol-impaired driving, greater risk of sexual assault, and greater symptoms of alcohol use disorder (Davis et al., 2019; Jackson et al., 2020; Read et al., 2021; Subbaraman & Kerr, 2015). Given the prevalence of simultaneous use and associated negative consequences, above and beyond those related to alcohol use alone, there is a need to better understand the risk and maintenance factors for simultaneous use to inform intervention efforts.

Cross-sectional and epidemiological survey studies have identified between-person risk factors for simultaneous use, including male sex (Lipperman-Kreda et al., 2018; Patrick, Kloska, et al., 2018), white race (Patrick, Kloska, et al., 2018; Terry-McElrath et al., 2013), using alcohol alone (i.e., in the absence of other people; Terry-McElrath et al., 2013), heavier alcohol use (Terry-McElrath et al., 2013), being higher on sensation seeking (Linden-Carmichael et al., 2019), having positive alcohol expectancies (Lipperman-Kreda et al., 2018), and greater peer substance use (Meisel et al., 2021). To build on this foundation, finer-grained examinations of the within-person processes that contribute to engaging in simultaneous use would help identify more proximal risk

factors that may be more feasible targets for intervention. Thus, the present study used ecological momentary assessment (EMA) to examine proximal predictors and consequences of simultaneous alcohol and cannabis use to better understand how this pattern of use is reinforced and identify possible targets for intervention. EMA minimizes retrospective bias, provides ecological validity, and allows for the analysis of within-person processes over time (Trull & Ebner-Priemer, 2013). Further, EMA is particularly well-suited for studying substance use, which is often episodic in nature and thought to be dependent on current or very recent affective states and social and physical contexts (Shiffman, 2009).

Motivational model of substance use

The motivational model of substance use places motives as the most proximal predictor of substance use and has received considerable empirical attention and support (Cooper et al., 2016; Cox & Klinger, 1988; Kuntsche et al., 2005). The model posits that individuals use substances to experience positive and negative reinforcement, which can be derived internally or externally. This results in four basic motives for use: coping (internal negative reinforcement, or to relieve negative affect), enhancement (internal positive reinforcement, or to increase positive affect), conformity (external negative reinforcement, or to avoid social rejection), and social motives (external positive reinforcement, or to make social settings more enjoyable; Cooper et al., 2016). Given the implied proximity of motives to substance use, this model provides a lens through which we can understand why individuals use substances and what they are hoping to achieve from that use.

EMA is uniquely positioned to shed light on motivational processes as they unfold in individuals' natural environments, yet studies using EMA to examine the motivational model as it relates specifically to the simultaneous use of alcohol and cannabis are only just starting to emerge (e.g., Jackson et al., 2021; Linden-Carmichael & Wardell, 2021; Patrick et al., 2020). In particular, Jackson et al. (2021) found that positive reinforcement motives (to be social and to enhance positive affect) and being in social situations with others who are using alcohol or cannabis were associated with greater odds of simultaneous use compared to use of cannabis alone. These findings are consistent with cross-sectional work finding that positive expectancies (Lipperman-Kreda et al., 2018) and social settings (Meisel et al., 2021) are risk factors for engaging in simultaneous use but bring the focus to the within-person level, suggesting that desired positive outcomes and social contexts are viable targets for intervention for individuals who use alcohol and cannabis simultaneously. Building on this, two of the premises of the motivational model that guide the present investigation are that *individuals use substances in order to achieve desirable affective outcomes*, and *substance use has different antecedents and consequences based on motive* (Cooper et al., 2016). These premises have the potential to directly inform reinforcement processes and intervention targets but have not been fully explored for simultaneous use. Thus, the present study sought to examine differential antecedents and affective consequences of substance use, depending on motive, as applied to simultaneous alcohol and cannabis use.

Baseline motives and daily-life affect predicting alcohol and cannabis use

Many researchers have used EMA to examine whether baseline alcohol use motives interact with daily-life affective states to predict alcohol use (Armeli et al., 2008;

Dvorak et al., 2014; Hussong, 2007; Hussong et al., 2005; Littlefield et al., 2012; Mohr et al., 2005; O'Hara et al., 2014; Todd et al., 2003; Todd et al., 2009; Wycoff et al., 2020). These investigations generally aimed to test whether negative affect predicts drinking among people with greater coping motives and whether positive affect predicts drinking among people with greater enhancement motives. These same ideas have not yet been explored for cannabis or its simultaneous use with alcohol. Motives for using different substances may differ within individuals (Cooper et al., 2016), and motives for using alcohol and cannabis *simultaneously* predict simultaneous use above and beyond motives for using alcohol or cannabis alone (Patrick, Fairlie, & Lee, 2018). Extending these investigations to the study of cannabis and its simultaneous use with alcohol may shed light on potential differences in motive-affect associations in predicting simultaneous versus single use of alcohol and cannabis. As such, **aim 1** of the present study was to a) replicate prior research using baseline coping and enhancement drinking motives and daily-life affective states to predict alcohol use, b) extend this to the study of cannabis by using baseline coping and enhancement motives for cannabis use and daily-life affective states to predict cannabis use, and c) extend this further to the study of *simultaneous* alcohol and cannabis use by using baseline coping and enhancement motives for simultaneous use and daily-life affective states to predict simultaneous use compared to the use of alcohol or cannabis alone.

Measuring motives in-the-moment

As the motivational model conceptualizes motives as the final and most proximal pathway leading to substance use (Cooper et al., 2016), recent research has focused on using EMA to measure substance use motives in-the-moment, during daily-life substance

use episodes, rather than solely at baseline (Votaw & Witkiewitz, 2021). Given the proximity of motives and use specified by the motivational model, measuring motives in-the-moment may provide more targeted evaluations of motivational processes, consistent with recommendations to more thoughtfully configure EMA designs to capture processes of interest at the timescales at which they naturally unfold (Hopwood et al., 2021). Therefore, the present study also measured momentary motives for alcohol and cannabis use during EMA whenever participants reported using alcohol, cannabis, or both.

Applying the premise of the motivational model that *substance use should have different antecedents based on motive* to the simultaneous use of multiple substances raises the possibility that motives for using one substance could depend on also using (or having recently used) another substance. Use of one substance could serve as a proximal predictor of one's motives for using the other, which could point to specific motivational factors that drive simultaneous use in the moment that it is occurring. Indeed, past work has shown that momentary enhancement and social motives for smoking cigarettes were endorsed more highly when individuals were simultaneously drinking alcohol compared to when individuals were only smoking cigarettes (Piasecki et al., 2007; Wycoff, Motschman, et al., 2021). Thus, **aim 2** of the present study was to examine whether momentary endorsement of alcohol and cannabis use motives depend on whether individuals were also simultaneously using the other substance.

Reinforcing effects of alcohol and cannabis use depending on motive

Finally, EMA is also well-suited to examine whether individuals experience the desirable affective outcomes of substance use that they are hoping to achieve. By capturing individuals' affective (coping and enhancement) motives for use *during*

substance use in daily life, we can specifically test whether positively and negatively reinforcing outcomes occur in the moments that individuals are reporting using alcohol or cannabis for those reasons. Even with EMA of daily-life motives being a relatively recent endeavor, surprisingly little work has examined whether individuals achieve the reinforcing effects that they report wanting from substance use. Existing work suggests that coping-motivated drinking is associated with endorsement of subjective drinking-contingent relief ("the drink relieved unpleasant feelings or symptoms") but no improvement in negative affect from the prior moment (Wycoff, Carpenter, et al., 2021) and that coping-motivated cannabis is associated with increased negative affect in the hour after use (Ross et al., 2018). Taken together, it does not appear that coping-motivated substance use is decidedly negatively reinforcing, though this work is preliminary. Therefore, **aim 3** of the present study was to examine the potentially reinforcing effects of alcohol and cannabis use based on how strongly individuals endorsed using them for the purpose of coping with negative affect or enhancing positive affect, and specifically whether also using the other substance simultaneously enhanced these reinforcing effects. Thus, results from aim 3 will not only inform whether individuals achieve the affective outcomes they report wanting in the moment from alcohol and cannabis use separately, but also whether simultaneous use affords an advantage over single-substance use in terms of desired affective reinforcements.

The current study

The current study used 14 days of EMA with a sample of individuals who reported regular simultaneous use of alcohol and cannabis to examine the proximal motivational predictors and consequences of simultaneous use. By characterizing the

motivational processes around this pattern of use as it unfolds in daily life, we may better understand how it is reinforced and identify potential intervention targets.

Aim 1 was to examine whether a) baseline coping and enhancement drinking motives interact with daily-life affective states to predict alcohol use, b) baseline coping and enhancement motives for cannabis use interact with daily-life affective states to predict cannabis use, and c) baseline coping and enhancement motives for simultaneous use interact with daily-life affective states to predict simultaneous use compared to the use of alcohol or cannabis alone. Aim 1 analyses and hypotheses were pre-registered at https://osf.io/8pz4u. Hypotheses were that a) individuals with greater baseline coping motives for alcohol use would be more likely to drink in daily life when negative affect has been higher than usual that day, and individuals with greater baseline enhancement motives for alcohol use would be more likely to drink in daily life when positive affect has been lower than usual that day; b) individuals with greater baseline coping motives for cannabis use would be more likely to use cannabis in daily life when negative affect has been higher than usual that day, and individuals with greater baseline enhancement motives for cannabis use would be more likely to use cannabis in daily life when positive affect has been lower than usual that day; and c) individuals with greater baseline coping motives for simultaneous use would be more likely to use alcohol and cannabis simultaneously in daily life (compared to using either alone) when negative affect has been higher than usual that day, and individuals with greater baseline enhancement motives for simultaneous use would be more likely to use alcohol and cannabis simultaneously in daily life (compared to using either alone) when positive affect has been lower than usual that day.

Aim 2 was to examine whether momentary endorsement of alcohol and cannabis use motives depend on whether individuals were simultaneously using the other substance. Specific motives included coping with anxiety, coping with depression, enhancement, social, conformity, expansion, and availability motives. Aim 2 analyses were pre-registered at https://osf.io/hmpes and we did not make a priori hypotheses given the lack of existing work investigating this question for simultaneous alcohol and cannabis use.

Aim 3 was to examine the potentially reinforcing effects of alcohol and cannabis use when individuals endorsed using for the purpose of coping with negative affect or enhancing positive affect, and whether simultaneously using the other substance enhanced these reinforcing effects. Aim 3 analyses and hypotheses were pre-registered at https://osf.io/dmfcb. First, we tested whether simultaneous *cannabis* use moderates the reinforcing effects of alcohol. Hypotheses included that simultaneously using cannabis during alcohol-use moments would strengthen the associations between momentary coping motives for alcohol use and variables indexing negatively reinforcing effects of alcohol (i.e., subjective drinking-contingent relief and change in negative affect); and simultaneously using cannabis during alcohol-use moments would strengthen the associations between momentary enhancement motives for alcohol use and variables indexing positively reinforcing effects of alcohol (i.e., subjective drinking-contingent pleasure and change in positive affect). Second, we tested whether simultaneous *alcohol* use moderates the reinforcing effects of cannabis. Hypotheses included that simultaneously using alcohol during cannabis-use moments would strengthen the associations between momentary coping motives for cannabis use and variables indexing

negatively reinforcing effects of cannabis (i.e., subjective cannabis-contingent relief and change in negative affect); and simultaneously using alcohol during cannabis-use moments would strengthen the associations between momentary enhancement motives for cannabis use and variables indexing positively reinforcing effects of cannabis (i.e., subjective cannabis-contingent pleasure and change in positive affect).

Chapter 2. Method

Participants

The sample included 88 individuals between the ages of 18 and 45. Participants had to own a smartphone, report using cannabis at least three times per week, and report using cannabis and alcohol simultaneously, such that their effects overlap, at least twice per week. Exclusion criteria included use of other illicit substances, being pregnant or planning to become pregnant, and history of head trauma that resulted in changes to mood, concentration, or memory. In addition, we excluded based on past-year physiological withdrawal symptoms for alcohol or cannabis, being in or seeking treatment for problems related to alcohol or cannabis use, and past-year unsuccessful efforts to cut down on or quit using alcohol or cannabis, to avoid inadvertently discouraging any potential efforts to change by paying individuals for a study on substance use. Finally, additional exclusion criteria included denying drinking at least 4 drinks (for women) or 5 drinks (for men) on at least one occasion in the past six months, having any medical contraindications for drinking alcohol, or having a history of flushing while drinking alcohol.[1]

The resulting sample (N = 88) had a mean age of 25.22 (SD = 6.91, *range* = 18 to 44) and were 60.2% female, 85.23% white, 93.2% not Hispanic or Latino, 87.5% single or never married, 51.1% currently enrolled or having completed some post high school education, 50% at an estimated household income level of $0 to $25,000 per year, and

[1] These exclusion criteria were used because we planned to include a laboratory alcohol administration component to the present study, which we ended up unable to execute due to the covid-19 pandemic.

77.3% currently employed. See Table 1 for demographic details and Table 2 for additional sample characteristics.

Procedures

Study procedures were approved by the Institutional Review Board of the University of Missouri (Protocol 2016077). Data collection occurred between August 2020 and June 2021. Participants were recruited from a previous EMA study from our lab and advertisements in a university-wide mailing list and on Facebook. After a phone screen to determine eligibility, participants were scheduled for a one-hour orientation session. Orientation sessions occurred remotely over Zoom, with the except of two participants toward the beginning of the study who came to the lab to participate in-person. During the *orientation session*, participants completed baseline demographic and self-report questionnaires online, downloaded the EMA app (TigerAware; Morrison et al., 2018) onto their smartphones, and were instructed on using the app to complete the EMA protocol. Participants were compensated $10 via Venmo or PayPal for their time.

Starting the day after the orientation session, participants completed *14 days of EMA*. Participants received a morning report daily at 7am and were instructed to complete this upon waking. *Morning reports* remained available until noon and had reminders at 9:15am and 11:30am if participants had not yet completed it. Participants then received five *random surveys* per day, one each per two-hour block of time between noon and 10pm. Random surveys were available for 20 minutes and reminders were sent 10 minutes after the initial notification if participants had not yet completed them. Participants were also instructed to complete *user-initiated substance use* surveys just after using alcohol, cannabis, or both. After reporting any substance use in any type of

survey, participants received two substance use *follow-up surveys* 60 and 120 minutes after the initial report of use. If additional substance use was reported in either of the follow-up surveys, additional follow-ups were administered hourly until participants reported no additional use in two consecutive surveys. When follow-ups were scheduled, any random prompts that were supposed to occur within that timeframe were cancelled to avoid overburdening participants. Participants had the option of suspending prompting during specified periods of time to avoid receiving surveys in situations when it would be inappropriate or unsafe to use their phone (e.g., while driving).

Finally, participants were scheduled for a brief Zoom meeting after the EMA period to coordinate payment and debrief. *Participants were compensated $80 for 80%+ total compliance to morning, random, and follow-up surveys.* Compensation was reduced by $10 for every 10% drop in compliance below 80%. Participants were not compensated if compliance was below 50%. Compliance was monitored each weekday while participants were in the study, and participants were contacted by phone if their compliance dropped below 80%. On average, morning report compliance was 87.19% (*SD* = 17.50, *range* = 25 to 100), random prompt compliance was 73.91% (*SD* = 17.01, *range* = 11.76 to 98.25), substance use follow-up compliance was 75.45% (*SD* = 19.50, *range* = 21.74 to 100), and total compliance across response types was 76.38% (*SD* = 15.61, *range* = 19.64 to 96.84). Participants on average completed 4.92 user-initiated substance use surveys (*SD* = 4.22, *range* = 0 to 19). The 88 participants included in the

present sample are those who completed *any* EMA surveys. Of those, 82 finished all 14 days of EMA, and of those 82, 78 had >50% compliance.[2]

Measures

See Tables 3-5 for descriptive statistics and correlations for all baseline and EMA measures analyzed in the present study.

Baseline measures

Motives for alcohol use. Participants completed the Modified Drinking Motives Questionnaire—Revised (Modified DMQ-R; Grant et al., 2007), which is a 28-item measure of five motives for drinking. Participants were asked to rate how often they drink alcohol for the following reasons on a scale from 1 (*almost never/never*) to 5 (*almost always/always*). We averaged item responses to create each motive subscale and used the coping-anxiety, coping-depression, and enhancement motive subscales in the present study. Cronbach's alphas were acceptable to good in our sample: coping-anxiety $\alpha = .66$, coping-depression $\alpha = .90$, enhancement $\alpha = .79$.

Motives for cannabis use. Participants completed the Comprehensive Marijuana Motives Questionnaire (CMMQ; Lee et al., 2009), which is a 36-item measure of 12 motives for cannabis use. Participants were asked to rate how often they use marijuana for the following reasons on a scale from 1 (*almost never/never*) to 5 (*almost always/always*). We averaged item responses to create each motive subscale and used the

[2] We conducted sensitivity analyses with the subset of individuals who finished the 14-day EMA study with >50% compliance, and the pattern of results remained the same. Therefore, we retained all 88 participants in the analyses reported here.

coping and enjoyment motives in the present study. Cronbach's alphas were good in our sample: coping α = .71, enhancement α = .71.

Motives for simultaneous alcohol and cannabis use. Participants completed a 22-item measure of four motives for simultaneous alcohol and marijuana use (Patrick, Fairlie, & Lee, 2018). Participants were asked to rate how often they use alcohol and marijuana "at the same time, so that their effects overlap," for the following reasons on a scale from 1 (*almost never/never*) to 5 (*almost always/always*). We averaged item responses to create each motive subscale and used the positive effects and coping motives in the present study. Cronbach's alphas were acceptable to good in our sample: coping α = .62, positive effects α = .89.

EMA measures

Alcohol, cannabis, and simultaneous use. During morning, random, and substance use follow-up surveys, participants were asked, "Have you used alcohol and/or cannabis since the last survey you answered?" When participants selected *yes* and when participants completed user-initiated substance use surveys (for which substance use was implied by making the report), they were asked which they had used since the last survey: *alcohol only*, *cannabis only*, or *both*. When participants selected *both*, they were asked whether they used them at the same time so that their effects overlapped. When participants selected one substance only, they were asked whether they had used the other substance *prior* to the last survey and, if *yes*, whether the effects overlapped. Instances of alcohol and cannabis use so that their effects overlapped were coded as moments of simultaneous use.

Affect. Negative and positive affect were assessed at each survey using 15 items from the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1992). Participants rated how much of each mood state they felt in the past 15 minutes on a scale of 1 (*very slightly or not at all*) to 5 (*extremely*). We measured anxious mood, depressed mood, anger, and vigor with three items each as specified in Cranford et al. (2006; POMS-15). Anxious mood items were, "on edge," "anxious," and "uneasy." Depressed mood items were, "hopeless," "discouraged," and "sad." Anger items were, "resentful," "angry," and "annoyed." Vigor items were, "cheerful," "lively," and "vigorous." Finally, we represented low arousal positive affect by measuring contentment with three items from the POMS: "relaxed," "at ease," and "calm." We averaged item responses to create each subscale. We also averaged across the nine negative affect items and the six positive affect items to create general negative and positive affect aggregates. Between- and within-person reliabilities were good to excellent for all aggregates: general negative affect within-person ω =.85 and between-person ω =.96, general positive affect within-person ω =.77 and between-person ω =.93, anxious mood within-person ω =.73 and between-person ω =.90, depressed mood within-person ω =.79 and between-person ω =.94, anger within-person ω =.73 and between-person ω =.89, vigor within-person ω =.73 and between-person ω =.87, and contentment within-person ω =.81 and between-person ω =.98 (Geldhof et al., 2014).

Motives for substance use. When participants reported alcohol use in any type of survey, they were asked to rate how much they had used alcohol for the following reasons: "to feel less anxious," (coping-anxiety), "to feel less depressed" (coping-depression), "to make a social gathering more enjoyable" (social), "because I like the

feeling" (enhancement), "to fit in with a group I like" (conformity), "to alter my perspective" (expansion), and "because it was available" (availability). When participants reported cannabis use in any type of survey, they were asked to rate how much they had used cannabis for the same seven reasons. When participants reported both alcohol and cannabis use in the same survey, they were asked their motives for each substance separately. Each item was rated on a scale from 1 (*very slightly or not at all*) to 5 (*extremely*). Items were selected and adapted for EMA from the Modified DMQ-R (Grant et al., 2007) and the CMMQ (Lee et al., 2009) based on a high factor loadings and wording consistency (e.g., we made the wording parallel for the two coping motives), and similar single-item motive items have been used in a past EMA study (Jackson et al., 2021).

Subjective appraisals of substance use. When participants reported alcohol use in any type of survey, they were asked to rate if the drinking was "pleasurable" and if the drinking "relieved unpleasant feelings or symptoms." When participants reported cannabis use in any type of survey, they were asked the same questions for cannabis. When participants reported both alcohol and cannabis use in the same survey, they were asked their subjective appraisals for each substance separately. Each item was rated on a scale from 1 (*very slightly or not at all*) to 5 (*extremely*). Items were taken from previous EMA studies using these items to assess subjective appraisals of alcohol use (Piasecki et al. 2014; Wycoff, Carpenter, et al., 2021).

Analytic method

Aim 1

First, to test the hypothesis that baseline coping and enhancement motives for alcohol use would moderate daily-life associations between affect and alcohol use, we used three[3] logistic multilevel models in SAS PROC GLIMMIX (Models 1-3). Each model had three levels with moments (level 1) nested within days (level 2) and days nested within person (level 3). The outcome for all three models was momentary alcohol use (yes/no since the last survey). The predictor effect of interest in Model 1 was the interaction between baseline coping-anxiety drinking motives and cumulative-average anxious mood, which averaged all momentary anxious mood ratings throughout the day prior to the current moment and was centered on person-means of anxious mood (as in Wycoff et al., 2020). We also included momentary anxious mood (centered on day-means of anxious mood) and person-level anxious mood (centered on the sample mean of anxious mood) as covariates to disaggregate the three levels of analysis (momentary, cumulative-average, and person level; Curran & Bauer, 2011). Additional covariates in Model 1 included momentary cannabis use (yes/no since the last survey), hour after wake, weekend (versus weekday), study day, age (centered on the sample), and gender (male compared to female or nonbinary). We specified a random intercept for person and a random intercept for days within people. We also tested a random slope for cumulative-average anxious mood and retained it if it exhibited significant variability. Models 2 and

[3] We had pre-registered two models for this part of Aim 1 but ended up using three because the Modified DMQ-R breaks coping into coping-anxiety and coping-depression (Grant et al., 2007). As such, we used two models for the two types of coping and one for enhancement, resulting in three models total.

3 were identical to Model 1 but tested coping-depression drinking motives × depressed mood and enhancement drinking motives × positive affect, respectively.

Second, to test the hypothesis that baseline coping and enhancement motives for cannabis use would moderate daily-life associations between affect and cannabis use, we used two logistic multilevel models in SAS PROC GLIMMIX (Models 4-5). These models were identical to Models 1-3 with the following exceptions: Models 4-5 predicted momentary cannabis use (yes/no since the last survey), used coping motives for cannabis use × negative affect and enhancement motives for cannabis use × positive affect as the predictors of interest, and included momentary alcohol use (yes/no since the last survey) as a covariate instead of cannabis use.

Third, to test our primary hypothesis that baseline coping and enhancement motives for simultaneous alcohol and cannabis use would moderate daily-life associations between affect and simultaneous use, we used two multinomial logistic multilevel models in SAS PROC GLIMMIX (Models 6-7). These were identical to Models 4-5 with the following exceptions: we restricted the dataset to observations with any substance use (alcohol, cannabis, or both); we predicted momentary simultaneous use (yes/no since the last survey) as a multinomial outcome variable with three levels to predict simultaneous use compared to using alcohol alone and compared to using cannabis alone; we specified a glogit link function to accommodate our multinomial outcome; we used coping and "positive effects" (enhancement) motives for simultaneous alcohol and cannabis use as our baseline motive predictors of interest; finally, we did not include alcohol or cannabis use as a covariate.

Aim 2

Unconditional models predicting momentary alcohol- and cannabis-use motives did not support the use of three-level multilevel models, as there was insufficient variability in cannabis motives at the day level (ICCs ranged from .06 for coping-depression to .14 for conformity). As such, we deviated from our pre-registered three-level models for Aim 2 and conducted two-level models (moments within person) instead.

To test whether momentary cannabis use motives depend on simultaneous alcohol use, we used seven multilevel models in SAS PROC MIXED (Models 8-14). The only difference among the seven models was the outcome variable, which was one of seven momentary cannabis use motives: coping-anxiety, coping-depression, social, enhancement, conformity, expansion, and availability. We restricted the dataset to observations with momentary cannabis use and the predictor of interest was momentary simultaneous alcohol use (yes/no). Covariates included person-means of alcohol use, presence of other people (yes/no)[4], hour after wake, weekend (versus weekday), study day, age (centered on the sample), and gender (male compared to female or nonbinary). Finally, we specified a random intercept for person and retained a random slope for momentary simultaneous alcohol use when significant.

To test whether momentary alcohol use motives depend on simultaneous cannabis use, we used six multilevel models in SAS PROC MIXED (Models 15-20). These

[4] We did not pre-register the presence of other people as a covariate but later decided to add it due to its likely association with social and conformity motives, to ensure that any observed results were not better explained by social context. Models without this covariate showed the same pattern of results.

mirrored Models 8-14 and used the six[5] momentary alcohol use motives as the outcome variables, used a dataset restricted to observations with momentary alcohol use, used momentary simultaneous cannabis use (yes/no) as the predictor of interest, included person-means of cannabis use as a covariate, and retained a random slope for momentary simultaneous cannabis use when significant. The rest of the covariates and random effects were the same as in Models 8-14.

Aim 3

In addition to the lack of sufficient day-level variability in cannabis use motives found for Aim 2 (three of which are used as predictor variables in Aim 3), unconditional models predicting momentary subjective appraisals of alcohol and cannabis use also did not support the use of three-level multilevel models. There was insufficient variability in day-level subjective appraisals of substance use (ICCs ranged from .07 for drinking-contingent relief to .15 for drinking-contingent pleasure). As such, we again deviated from our pre-registered three-level models for Aim 3 and conducted two-level models (moments within person) instead.

First, to test the hypothesis that simultaneous cannabis use would strengthen associations between coping motives for alcohol use and negatively reinforcing effects of drinking, we used four multilevel models in SAS PROC MIXED (Models 21-24). The dataset for all four models was restricted to observations with alcohol use. Model 21 used the interaction of momentary coping-anxiety motives for drinking (centered on person

[5] The conformity motive item for alcohol use was inadvertently left out of the EMA protocol when participants reported only using alcohol (and not cannabis). Thus, we could not model this motive in alcohol-specific analyses.

means) and momentary simultaneous cannabis use to predict subjective drinking-contingent relief. Model 22 was identical to Model 21 but used momentary coping-depression motives for drinking.[6] Model 23 was identical to Model 21 but predicted change in anxious mood (current-moment anxious mood minus anxious mood at the last survey) and controlled for anxious mood at the last survey. Model 23 was identical to Model 24 but used momentary coping-depression motives for drinking to predict change in depressed mood, while controlling for depressed mood at the last survey. All four models also included the following covariates: person-means of the momentary drinking motive of interest (centered on the sample mean), person-means of cannabis use, the matching baseline coping motive (-depression or -anxiety) from the Modified DMQ-R (Grant et al., 2007), hour after wake, weekend (versus weekday), study day, age (centered on the sample), and gender (male compared to female or nonbinary). Finally, all four models included a random intercept for person and retained a random slope for momentary simultaneous cannabis use when significant.

Second, to test the hypothesis that simultaneous cannabis use would strengthen associations among enhancement motives for alcohol use and positively reinforcing effects of drinking, we used two multilevel models in SAS PROC MIXED (Models 25-26). Model 25 was identical to Model 21 but used the interaction of momentary enhancement motives for drinking (centered on person means) and momentary

[6] We deviated from our pre-registration by separating coping-anxiety and coping-depression motive predictors into separate models due to their high correlation. For alcohol, coping-anxiety and coping-depression motives were correlated .71 ($p < .001$) and for cannabis, coping-anxiety and coping-depression motives were correlated .69 ($p < .001$).

simultaneous cannabis use to predict subjective drinking-contingent pleasure. Model 26 was identical to Model 23 but used momentary enhancement motives to predict change in positive affect while controlling for positive affect at the last survey.

Third, to test the hypothesis that simultaneous alcohol use would strengthen associations among coping motives for cannabis use and negatively reinforcing effects of cannabis, we used four multilevel models in SAS PROC MIXED (Models 27-30). Models 27-30 were identical to Models 21-25 but used a dataset that was restricted to observations with cannabis use and flipped alcohol and cannabis variables. I.e., Models 27-28 used cannabis motives to predict cannabis-contingent relief, Models 29-30 used cannabis motives to predict change in negative affect, and all four models used simultaneous alcohol use as the moderator of motive-outcome associations.

Fourth, to test the hypothesis that simultaneous alcohol use would strengthen associations among enhancement motives for cannabis use and positively reinforcing effects of cannabis, we use two multilevel models in SAS PROC MIXED (Models 31-32). Models 31-32 were identical to Models 26-27 but again used a dataset that was restricted to observations with cannabis use and flipped alcohol and cannabis variables.

Chapter 3. Results

The final dataset had 6,334 observations. On average, participants reported alcohol use on 5.20 days during the study (*SD* = 3.15, *range* = 0 to 14), cannabis use on 8.56 days during the study (*SD* = 4.20, *range* = 0 to 15), and simultaneous use on 3.40 days during the study (*SD* = 2.95, *range* = 0 to 13). Participants reported on average 4.92 drinks on drinking days (*SD* = 5.33, *range* = 1 to 49).[7] Participants reported using dry leaf cannabis at 68.2% of cannabis-use moments, cannabis concentrate at 25.8% of cannabis-use moments, and edible cannabis at 6.0% of cannabis-use moments. During moments when participants reported using dry leaf cannabis, average self-reported THC content was 21.33% (*SD* = 6.59, *range* = 1 to 40)[8], and number of grams used since the last survey was reported as ¼ gram or less at 57.5% of moments with dry leaf cannabis use. Of moments when participants reported using cannabis concentrate, the most common method of use was with a dab rig (53.4% of use moments), followed by vaporizer (45.6%) and bong (1.0%). Average self-reported THC content of cannabis concentrate was 72.8% (*SD* = 19.2, *range* = 11 to 100) and average number of hits taken of cannabis concentrate since the last survey was 3.08 (*SD* = 3.23, *range* = 1 to 20). Finally, of moments when participants reported consuming edible cannabis, average quantity consumed was 25.15 mg (*SD* = 20.44, *range* = 2 to 50).

[7] One participant accounted for the higher end of these drink totals and was the only person who reported more than 25 standard drinks on a given day. Analyses without this participant in the dataset showed the same pattern of results as those including this participant.

[8] We set 40% as the upper limit on THC content of dry leaf cannabis. It is possible that some participants would have reported that the THC content of their dry leaf cannabis exceeded that.

Aim 1 results

Predicting alcohol use

Results from Models 1-3 using baseline drinking motives and daily-life affect to predict momentary alcohol use are reported in Table 6. All 6,334 observations were included in Models 1-3, and of those, 13.7% had alcohol use. In Model 1, the hypothesized interaction between baseline coping-anxiety drinking motives and cumulative-average anxious mood was not significant, nor were the main effects of baseline coping-anxiety motives or cumulative-average anxious mood. Similarly, in Model 2, the hypothesized interaction between baseline coping-depression drinking motives and cumulative-average depressed mood was not significant, nor were the main effects of baseline coping-depression motives or cumulative-average depressed mood. Finally, in Model 3, the hypothesized interaction between baseline enhancement drinking motives and cumulative-average positive mood was not significant, nor was the main effect of baseline enhancement motives, but cumulative-average positive mood was positively related to the likelihood of drinking alcohol in the moment.

Predicting cannabis use

Results from Models 4 and 5 using baseline cannabis-use motives and daily-life affect to predict momentary cannabis use are reported in Table 7. All 6,334 observations were included in Models 4-5, and of those, 24.0% had cannabis use. In Model 4, the hypothesized interaction between baseline coping motives for cannabis use and cumulative-average negative mood was not significant, nor were the main effects of baseline coping motives or cumulative-average negative mood. In Model 5, the hypothesized interaction between baseline enhancement motives for cannabis use and

cumulative-average positive mood was not significant, nor was the main effect of cumulative-average positive mood, but baseline enhancement motives for cannabis use were positively related to the momentary likelihood of using cannabis.

Predicting simultaneous use

Results from Models 6 and 7 using baseline motives for simultaneous alcohol and cannabis use and daily-life affect to predict momentary simultaneous use are reported in Table 8. Observations with *any* substance use (alcohol alone, cannabis alone, or both; n = 1,983) were included in these models. Of those, 27.0% had simultaneous use. In Model 6, the hypothesized interaction between baseline coping motives for simultaneous use and cumulative-average negative mood was not significant, nor were the main effects of baseline coping motives or cumulative-average negative mood. In Model 7, the hypothesized interaction between baseline positive effects motives for simultaneous use and cumulative-average positive mood was not significant, nor was the main effect of baseline positive effects motives, but cumulative-average positive mood was positively associated with simultaneous use compared to using cannabis alone.

Aim 2 results

Predicting cannabis motives

Results from Models 8-14 using simultaneous alcohol use to predict momentary endorsement of cannabis-use motives are reported in Table 9. Observations with cannabis use (n = 1,519) were included in these models, and of those, 29.9% had simultaneous alcohol use. Simultaneous alcohol use was positively associated with social, conformity, and expansion motives for cannabis use. Simultaneous alcohol use was not associated

with endorsement of coping-anxiety, coping-depression, enhancement, or availability motives for cannabis use.

Predicting alcohol motives

Results from Models 15-20 using simultaneous cannabis use to predict momentary endorsement of alcohol-use motives are reported in Table 10. Observations with alcohol use (n = 868) were included in these models, and of those, 54.3% had simultaneous cannabis use. Simultaneous cannabis use was positively associated with social and expansion motives for alcohol use. Simultaneous cannabis use was not associated with coping-anxiety, coping-depression, enhancement, or availability motives for alcohol use.

Aim 3 results

Does simultaneous cannabis use strengthen the reinforcing effects of alcohol?

Results from Models 21-26 using momentary drinking motives and simultaneous cannabis use to predict the reinforcing effects of alcohol are reported in Tables 11-14. Observations with alcohol use (n = 868) were included in these models and, of those, 54.3% had simultaneous cannabis use. In Model 21, greater momentary endorsement of coping-anxiety drinking motives predicted greater endorsement of drinking-contingent relief. However, using cannabis simultaneously attenuated this such that the association between momentary coping-anxiety drinking motives and drinking-contingent relief was no longer significant during simultaneous use moments (Table 11; simple slope for coping-anxiety drinking motives during simultaneous use moments: b = 0.14, *95% CI* = [-0.00, 0.28], p = .055). In Model 22, greater momentary endorsement of coping-

depression drinking motives predicted greater endorsement of drinking-contingent relief, and this association was not moderated by simultaneous cannabis use (Table 11).

In Model 23, greater momentary endorsement of coping-anxiety drinking motives predicted an increase in anxious mood from the last moment. Using cannabis simultaneously attenuated this such that the association between momentary coping-anxiety drinking motives and change in anxious mood was still significant but to a lesser extent during simultaneous use moments (Table 12; simple slope for coping-anxiety drinking motives during simultaneous use moments: $b = 0.10$, *95% CI* = [0.02, 0.17], $p = .012$). Similarly, in Model 24, greater momentary endorsement of coping-depression drinking motives predicted an increase in depressed mood from the last moment. Using cannabis simultaneously also attenuated this such that the association between momentary coping-depression drinking motives and change in depressed mood was still significant but to a lesser extent during simultaneous use moments (Table 12; simple slope for coping-depression drinking motives during simultaneous use moments: $b = 0.13$, *95% CI* = [0.01, 0.24], $p = .031$).

In Model 25, greater momentary endorsement of enhancement drinking motives predicted greater endorsement of drinking-contingent pleasure. Using cannabis simultaneously attenuated this such that the association between momentary enhancement drinking motives and drinking-contingent pleasure was still significant but to a lesser extent during simultaneous use moments (Table 13; simple slope for enhancement drinking motives during simultaneous use moments: $b = 0.15$, *95% CI* = [0.02, 0.27], $p = .022$). Finally, in Model 26, greater momentary endorsement of enhancement drinking motives predicted an increase in positive mood from the last

moment. Using cannabis simultaneously was also positively associated with change in positive affect from the last moment but did not moderate the association between enhancement drinking motives and increased positive mood (Table 14).

Does simultaneous alcohol use strengthen the reinforcing effects of cannabis?

Results from Models 27-32 using momentary cannabis use motives and simultaneous alcohol use to predict the reinforcing effects of cannabis are reported in Tables 15-18. Observations with cannabis use (n = 1,519) were included in these models and, of those, 29.9% had simultaneous alcohol use. In Model 27, greater momentary endorsement of coping-anxiety cannabis-use motives predicted greater endorsement of cannabis-contingent relief. Using alcohol simultaneously did not moderate this association (Table 15). Similarly, in Model 28, greater momentary endorsement of coping-depression cannabis-use motives predicted greater endorsement of cannabis-contingent relief and using alcohol simultaneously did not moderate this association (Table 15).

In Model 29, greater momentary endorsement of coping-anxiety cannabis-use motives predicted an increase in anxious mood from the last moment and using alcohol simultaneously did not moderate this association (Table 16). Similarly, in Model 30, greater momentary endorsement of coping-depression cannabis-use motives predicted an increase in depressed mood from the last moment and using alcohol simultaneously did not moderate this association (Table 16).

In Model 31, greater momentary endorsement of enhancement cannabis-use motives predicted greater endorsement of cannabis-contingent pleasure and simultaneous alcohol use did not moderate this association (Table 17). Finally, in Model 32, greater

momentary endorsement of enhancement cannabis-use motives predicted an increase in positive mood from the last moment. Using alcohol simultaneously was also positively associated with change in positive affect from the last moment but did not moderate the association between enhancement cannabis-use motives and increased positive mood (Table 18).

Chapter 4. Discussion

The present study sought to examine the motivational processes surrounding simultaneous alcohol and cannabis use in individuals' daily lives. We tested whether baseline motives for simultaneous use interacted with daily-life affective states to predict simultaneous use, compared to using alcohol or cannabis alone. We also tested whether individuals endorsed *momentary* motives for alcohol and cannabis to different extents depending on whether they were also using the other substance simultaneously. Finally, we tested whether individuals experienced the reinforcing effects that they were hoping to achieve when using alcohol or cannabis (based on their self-reported motives in the moment) and whether simultaneous use of the other substance enhanced those reinforcing effects. Collectively, findings from the present study inform our understanding of why individuals engage in simultaneous use of alcohol and cannabis and how this pattern of use is experienced and reinforced. Continued characterization of these motivational and reinforcement processes will facilitate more targeted intervention strategies aimed at reducing problematic patterns of substance use.

Aim 1 summary

Findings from aim 1 include that baseline motives for alcohol, cannabis, and simultaneous use did not moderate affect-use associations in daily life. However, a few notable main effects included that greater within-person positive affect throughout the day, up until the current moment, predicted greater odds of drinking alcohol in the moment. Similarly, greater within-person positive affect throughout the day predicted greater odds of using alcohol and cannabis simultaneously, compared to using cannabis alone. Taken together, results support a positive association between positive affect

throughout the day and subsequent alcohol use, even when participants are also using cannabis at the same time. This is consistent with existing literature on the link between positive mood states and alcohol use (e.g., Treloar et al., 2015). In contrast, only baseline enhancement motives were associated with greater odds of cannabis use at any given moment during the study. The lack of significant interactions between baseline motives and daily-life affect is not entirely surprising, given mixed findings in the alcohol literature for these associations (e.g., Hussong et al., 2005; Littlefield et al., 2012; Mohr et al., 2005; Todd et al., 2009; Wycoff et al., 2020) as well as the mixed findings in the cannabis literature of affect-use associations, regardless of motive (Wycoff et al., 2018). It is plausible that measuring motives at baseline and treating them as trait-like constructs may not provide enough information to clarify the day-to-day associations between affect and substance use, supporting the rationale for examining motives with more precision at the momentary level (Votaw & Witkiewitz, 2021).

Aim 2 summary

Findings from Aim 2 demonstrate that momentary motive endorsement did differ in some ways during simultaneous versus single substance use moments. Specifically, simultaneously using alcohol was associated with greater momentary endorsement of social, conformity, and expansion motives for cannabis use. Mirroring this, simultaneously using cannabis was associated with greater momentary endorsement of social and expansion motives for drinking. Notably, these effects were significant when adjusting for the presence of other people. The current findings regarding social motives are consistent with the finding by Jackson et al. (2021) that momentary social motives predicted simultaneous use compared to using cannabis alone but extends our

understanding from the lens of alcohol use too, such that social motives were endorsed more highly during simultaneous use moments compared to alcohol only moments as well. In our study, simultaneous use also predicted greater expansion motives for each substance compared to using each substance alone. This differs from findings by Jackson et al. (2021), wherein use moments with expansion motives were more likely to be cannabis-only compared to simultaneous use moments. This discrepancy could come from a number of sources including the sample, as ours included slightly older participants (as opposed to college students) who reported more frequent simultaneous use, or the way we assessed motives with Likert-style responses instead of check boxes (yes/no as in Jackson et al., 2021). Future work should further examine the possibility that expansion motives could become predictive of alcohol use in contexts where cannabis is also being used, especially given that expansion is generally considered a cannabis-specific motive with less relevance to alcohol (Cooper et al., 2016).

We also found that conformity motives for cannabis use were endorsed more highly when participants were also using alcohol simultaneously. This was somewhat surprising, given relatively low endorsement of conformity motives among individuals who regularly use alcohol or cannabis, as in our sample, as well as relatively weaker associations among conformity motives and substance use in general (Cooper et al., 2016; Votaw & Witkiewitz, 2021). Thus, our finding may implicate conformity motives as a potential pathway to simultaneous compared to single-substance use. That is, conformity motives may become more influential for cannabis use *when used alongside alcohol* and may be important to consider in contexts where alcohol is also being used. Although conformity motives are often the least endorsed and are the least related to

quantity and frequency of substance use, they are also associated with use-related problems and negative consequences (Cooper et al., 2016; Patrick, Fairlie, & Lee, 2018). Combined with the added risks related to simultaneous versus single substance use, replication of our finding and further investigation of the contexts in which conformity motives may drive simultaneous use and confer risk for substance-related problems is warranted. For instance, examining whether conformity motives are endorsed more highly in certain social situations (e.g., with friends, with acquaintances, with perceived peer pressure) may refine our understanding of when individuals might be most at risk of engaging in a particularly risky pattern of cannabis use (i.e., simultaneous use with alcohol) with a particularly risky motive for use (conformity). Further, investigating whether positive social outcomes are achieved during conformity-motivated simultaneous use may inform whether and how this use is reinforced. Finally, investigating whether negative consequences are experienced during or after simultaneous use events driven by conformity motives may inform how conformity-motivated use specifically confers risk for substance-related problems.

Aim 3 summary

Findings from Aim 3 suggest that simultaneous cannabis use alters several of the affect-related effects of alcohol use, whereas simultaneous alcohol use does not appear to alter the affect-related effects of cannabis. Specifically, regarding how simultaneous cannabis use alters the potentially negatively reinforcing effects of alcohol, the positive association between momentary coping-anxiety drinking motives and subjective drinking-contingent relief was only present when using alcohol by itself and not when using cannabis simultaneously. This might suggest that, when participants report drinking

alcohol to feel less anxious, alcohol use by itself provides more relief than simultaneous use. However, evidence that coping-anxiety drinking was associated with an *increase* in anxious mood and that simultaneous cannabis use was associated with *less* of an increase in anxious mood introduces several discrepancies and complicates the picture. Coping-depression drinking was also associated with an increase in depressed mood, with simultaneous cannabis use predicting less of an increase in depressed mood.

Taken together, it may be most plausible that a few things are happening. First, there appears to be a discrepancy between greater perceived subjective relief from alcohol versus a worsening of anxious mood during drinking moments characterized by higher coping-anxiety motives. Existing EMA work demonstrates a similar discrepancy with greater perceived subjective relief from alcohol versus no improvement in anxious mood during moments with higher coping-anxiety motives (Wycoff, Carpenter, et al., 2021). Results from the present coping-depression models parallel this, with greater perceived drinking-contingent relief versus increased depressed mood during drinking moments characterized by higher coping-depression motives. Collectively, the present evidence supports the idea that coping-motivated drinking may be reinforced and maintained by *perceived* relief, whereas a lack of improvement (or even a worsening) in negative affective states may be a useful source of counterevidence in intervention when evaluating whether alcohol use is an effective coping strategy. Further, the consistent worsening in negative affect points to a possible avenue through which coping motives may contribute to alcohol-related problems (Cooper et al., 2016).

Second, the interpretation that alcohol use alone may be more relieving than simultaneous use does not fit with the finding that simultaneous use was related to less of

an increase in anxious mood compared to coping-anxiety-motivated drinking alone. Given that we asked participants to rate use-contingent-relief as attributed to alcohol and cannabis separately, even during moments when they reported using both substances, it may be possible that participants are attributing any benefit of simultaneous use to cannabis specifically, and not alcohol, even when participants are reporting drinking to feel less anxious. The idea that individuals could be attributing improvements in affect during simultaneous use to cannabis rather than to alcohol warrants further investigation, as it has potential to inform whether individuals use certain substances to offset or balance out the effects of another substance (e.g., using cannabis to offset the negative effects of alcohol, which was tested but not ultimately retained as a motive item in Patrick et al., 2018).

Third, given attenuated increases in anxiety and depression during simultaneous compared to alcohol-only moments motivated by coping with respective affective states, it appears that simultaneously using cannabis alongside alcohol may improve the affective experience relative to that when only drinking. Rather than interpreting this as support for our hypothesis that simultaneous use moments would be associated with more negatively *reinforcing* effects than single-use moments, though, it may be more appropriate to conclude that simultaneous use moments are associated with less *worsening* of negative affect than alcohol-only use in our study. That is, our finding that negative affect increased during both alcohol-only and simultaneous use moments suggests that both instances of use are accompanied by undesirable negative affective changes and that simultaneous cannabis use may partially offset the increase in negative affect expected from coping-motivated drinking.

Our examination of how simultaneous cannabis use may alter the potentially *positively* reinforcing effects of alcohol demonstrated that the positive association between momentary enhancement drinking motives and subjective drinking-contingent pleasure was attenuated by simultaneous cannabis use such that simultaneous use was positively associated with drinking-contingent pleasure, just to a lesser extent than when only drinking. Together with evidence that simultaneous cannabis use did not alter the positive association between enhancement drinking motives and change in positive affect, this suggests that a similar attribution shift may be present for the pleasurable effects of simultaneous use as that which may be present for perceived relief. That is, it may not be that simultaneous use is less pleasurable than only using alcohol; rather, the perceived pleasure experienced during simultaneous use may be a similar amount as perceived during alcohol use alone and participants attribute more of that pleasure to the effects of cannabis more so than to alcohol during simultaneous use moments.

Finally, we found that simultaneous *alcohol* use did not moderate any of the potentially reinforcing effects of *cannabis*. Notably, however, findings did include a similar discrepancy between perceptions of relief versus change in negative affect as that which was found for alcohol. Cannabis use moments motivated by coping-anxiety and coping-depression were positively associated with subjective cannabis-contingent relief despite also being associated with increases in anxious and depressed mood, respectively.

Clinical implications

Given the null interaction effects found in Aim 1 examining whether baseline motives for substance use moderate affect-use associations in daily life, it appears that individuals' self-reported "typical" motives for use may not provide that much useful

information about risk of using alcohol, cannabis, or both simultaneously at any given moment. Instead, it appears more fruitful to consider *momentary* motives for substance use at specific episodes of use, as the strength of motives fluctuate within person and may be accompanied by different perceived reinforcements. Our findings that simultaneous use moments were associated with greater social and conformity motives suggest that anticipated reinforcements within peer contexts may drive simultaneous compared to single-substance use. Discussions around social rewards and peer pressure in interventions targeting simultaneous use may facilitate conversations around how else individuals might achieve desirable social outcomes without relying on a pattern of use that may cause problems for them. In addition, we found that expansion motives for both alcohol and cannabis were endorsed more highly during simultaneous use moments compared to single-use moments. It may be worth considering how expansion motives relate to alcohol, in the context of simultaneous cannabis use, to facilitate a more thorough understanding of simultaneous use in individuals seeking to make changes in their substance use that might otherwise be missed when thinking of expansion motives as only relevant to cannabis. Patrick et al. (2018) included the item, "to get to a greater altered state," in their measure of motives for simultaneous alcohol and cannabis use as part of the "positive effects"/enhancement subscale, similar to the wording of our expansion motive in the present study ("to alter my perspective"). It may be worth qualitatively investigating what it means to have expansion motives specifically for simultaneous use of alcohol and cannabis and whether and how those desired effects differ from expansion effects of using cannabis alone.

The consistent discrepancy between coping-motivated alcohol and cannabis use moments being perceived as providing relief from unpleasant feelings or symptoms while also being accompanied by momentary *increases* in negative affect may be important to explore in treatment. The validation that perceived relief during coping-motivated use likely feels very reinforcing, alongside the possibility that anxious and depressed mood may be exacerbated by such use, could comprise a helpful balance in challenging the idea that substance use is an effective emotion-regulation strategy. To that end, increased awareness of momentary motives for use and reflection on emotional states surrounding substance use could help individuals feel more equipped to make reasonable changes when moderation or harm reduction is the treatment goal. To take this a step further, future work might examine whether perceived relief versus changes in negative affect differentially predict likelihood of future engagement in using substances to cope to inform those aspects of the reinforcement cycle. Similarly, future work might examine whether perceived relief versus changes in negative affect differentially predict the likelihood of experiencing negative use-related consequences to highlight additional clinically relevant outcomes that may stem from coping-motivated substance use.

Finally, the idea that perceived relief during simultaneous use moments could be attributed to cannabis rather than to alcohol, even when individuals endorse drinking to cope, could be valuable to explore in treatment. Combined with evidence that simultaneous cannabis use may mitigate the worsening of negative affect when drinking to cope, it appears that there may indeed be some benefit of using cannabis simultaneously with alcohol when using substances to feel less anxious or depressed, and that individuals pick up on this added benefit if they are attributing perceived relief to

cannabis rather than alcohol. This requires further exploration, and some care would be needed to avoid encouraging simultaneous use as a way to attenuate negative effects of alcohol, but acknowledging the potential benefit of cannabis in terms of negative affective experiences could go a long way in promoting and validating honest client self-reflections on how exactly simultaneous use might feel more relieving than alcohol use alone when drinking to cope.

Limitations and future directions

The present study had several notable limitations. First, we used single items to capture motives for alcohol and cannabis use during the EMA period. Given the number of items being collected by our EMA study and the frequency at which we prompted participants within each day, the choice to use single items to assess motives was meant to reduce participant burden and is consistent with similar EMA work measuring motives for alcohol and cannabis use (Jackson et al., 2021). However, assessment of the validity of single- versus multi-item assessments of momentary motives in EMA is needed. There may be some instances in which single-item measures may be appropriate (Allen et al., 2022), but this should be explored in future work, especially since motives are typically measured with multiple items in cross-sectional studies (e.g., Grant et al., 2007).

Second, we assessed momentary motives for substance use whenever participants reported using alcohol or cannabis *since the last survey*. Although the timing between substance use and assessing motives for that use was relatively proximal, measuring motives right *before* use would more closely map onto motivational models of substance use in which motives are the most proximal predictor of use (Cooper et al., 2016; Kuntsche et al., 2005). Further, assessing motives for use right after use could allow

actual experienced effects to influence what motives individuals endorse. If a participant had a drink for social purposes but also experienced some relief from anxiety, they might understandably highly endorse coping-anxiety motives for drinking. Assessing motives before use would require assessment of immediate intentions to use alcohol or cannabis or require participants to self-initiate surveys when intending to use, which could add to participant burden. However, this would also provide important information on whether coping-motivated substance use moments are still associated with subjective relief if the two constructs are not assessed at the same time-point and is a worthwhile avenue of future work.

Third, we did not assess motives for using cannabis or alcohol to offset effects of the other substance. This was a conscious choice due to those items ultimately being left out of the measure of simultaneous use motives by Patrick et al. (2018). However, given that simultaneous cannabis use appeared to mitigate worsened mood during drinking-to-cope moments, assessing motives for using cannabis to offset negative effects of alcohol could help highlight this effect and, if consistent with what we found, could be useful in future research and clinical assessment.

Fourth, generalizability of the present results is limited based on the characteristics of our sample and our explicit exclusion criteria. We excluded individuals who were in or seeking treatment for substance use, reported past-year unsuccessful attempts to stop or cut down, or reported severe past-year withdrawal symptoms. Although AUDIT (Saunders et al., 1993) and CUDIT-R scores (Adamson et al., 2010) and frequency of alcohol and cannabis use in the last 30 days indicate sizable variability (Table 2), it is possible that associations among motives and the affective and reinforcing

properties around simultaneous use would look different for individuals in or seeking treatment or recognizing severe substance-related problems. Future work might recruit individuals seeking treatment or meeting criteria for moderate to severe substance use disorders specifically, as clinical implications of this work will be most relevant and useful to that population.

Conclusions

The present study used EMA to examine motivational and reinforcement processes surrounding simultaneous alcohol and cannabis use in daily life. First, we found limited utility of using baseline motives for alcohol, cannabis, and their simultaneous use as moderators of affect-use associations in daily life. Second, we found increased social, expansion, and conformity motives during simultaneous use moments compared to single-substance use moments, highlighting these as potential drivers of simultaneous use and supporting the assessment of motives as momentary constructs during individuals' daily-life substance use episodes. Third, we found that cannabis use may attenuate the increase in negative affect during drinking to cope, pointing to simultaneous cannabis use as a way that individuals might offset negative effects of alcohol. Finally, we found that using alcohol and cannabis to cope is associated with endorsement of use-contingent relief despite also being accompanied by a worsening of negative affect. Together, findings from this study inform our understanding of what experiences individuals are hoping to achieve by using alcohol and cannabis simultaneously and how this pattern of use could be reinforced. Future work should continue characterizing these motivational and reinforcement processes, especially with

samples of individuals in or seeking treatment for substance use, with the goal of creating more targeted intervention strategies for reducing problematic patterns of substance use.

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Table 1

Demographic information

Demographic categories	*n*	%
Gender identity		
Male	34	38.6
Female	53	60.2
Nonbinary	1	1.1
Race		
American Indian or Alaska native	3	3.4
Asian or Asian American	4	4.6
Black or African American	7	8.0
Native Hawaiian or other Pacific Islander	1	1.1
White	75	85.2
Other (write in)	4	4.6
Hispanic or Latino	2	2.3
Mexican	1	1.1
Sri Lankan	1	1.1
Ethnicity		
Hispanic or Latino	6	6.8
Marital status		
Single or never married	77	87.5
Married	6	6.8
Divorced	3	3.4
Separated	1	1.1
Living with someone as married	1	1.1
Highest level of education completed		
High school or equivalent	12	13.6
Some post high school education (includes currently enrolled)	45	51.1
Vocational or technical program	2	2.3
Undergraduate degree	10	11.4
Some post graduate education (includes currently enrolled)	10	11.4
Graduate degree	9	10.2
Annual household income		
$0 to $25,000	44	50.0
$25,001 to $50,000	23	26.1
$50,001 to $75,000	5	5.7
$75,001 to $100,000	5	5.7
Above $100,000	11	12.5
Employed	68	77.3

Table 2

Baseline sample characteristics

Sample characteristics	*Mean*	*SD*	*Range*
AUDIT	10.45	4.91	3 to 26
CUDIT-R	10.92	5.67	3 to 25
PHQ-9	5.41	4.59	0 to 21
GAD-7	5.10	4.22	0 to 19
Age at first alcohol use	14.59	2.62	6 to 22
Age at first cannabis use	16.27	3.47	8 to 31
Age at first simultaneous use	17.31	3.31	12 to 31
Past 30-day Timeline Follow-Back			
Alcohol use frequency (number of use days)	14.19	6.04	0 to 30
Cannabis use frequency (number of use days)	23.49	7.21	10 to 30
	n	*%*	
Medicinal or recreational cannabis use			
Medicinally only	3	3.5	
Recreationally only	41	47.7	
Mix of both medicinal and recreational	42	48.8	
Past month use of other substances (yes/no)			
LSD	3	3.4	
MDMA	6	6.8	
Amphetamines	6	6.8	
Benzodiazepines	5	5.8	
Cocaine	3	3.4	
Opioid	1	1.1	
Methamphetamine	1	1.1	
Inhalants	2	2.3	

Note. AUDIT = Alcohol Use Disorders Identification Test. CUDIT-R = Cannabis Use Disorder Identification Test—Revised. PHQ-9 = Patient Health Questionnaire—9. GAD-7 = Generalized Anxiety Disorder—7. LSD = lysergic acid diethylamide. MDMA = 3,4-methylenedioxy-methamphetamine.

Table 3

Descriptive statistics and correlations for measures analyzed in Aim 1

				Correlations												
Aim 1 measures	*M*	*SD*	*range*	1	2	3	4	5	6	7	8	9	10	11	12	13
Baseline alcohol use motives																
1. Coping-anxiety	2.34	0.81	1 to 4.5													
2. Coping-depression	1.55	0.65	1 to 4.44	.69***												
3. Enhancement	3.01	0.91	1 to 5	.37***	.37***											
Baseline cannabis use motives																
4. Coping	1.91	0.85	1 to 4.67	.30**	.48***	.08										
5. Enhancement	4.20	0.77	1.33 to 5	.17	.14	.40***	.30**									
Baseline simultaneous use motives																
6. Coping	2.53	1.20	1 to 5	.45***	.33**	-.08	.26*	.07								
7. Positive effects	3.17	1.10	1 to 5	.23*	.24*	.32**	.24*	.34**	.28**							
Momentary substance use																
8. Alcohol use	0.14	0.11	0 to 0.74	.18	.16	.12	.01	.06	.16	.02						
9. Cannabis use	0.24	0.16	0 to 0.59	.04	.00	-.05	.10	.21*	.11	-.07	.40***					
10. Simultaneous use	0.09	0.09	0 to 0.59	.14	.12	.05	.01	.13	.19	-.02	.81***	.61***				
Momentary affective states																
11. Negative mood	1.23	0.23	1 to 2.10	.43***	.47***	.17	.50***	.07	.11	.13	.20	.12	.09			
12. Anxious mood	1.32	0.29	1 to 2.27	.47***	.42***	.22*	.43***	.10	.11	.12	.21	.11	.11	.94***		
13. Depressed mood	1.19	0.24	1 to 2.25	.37***	.49***	.14	.49***	-.00	.11	.12	.19	.10	.04	.93***	.80***	
14. Positive mood	2.32	0.57	1.20 to 4.00	-.01	-.16	.09	-.08	.17	.09	.10	.33**	-.00	.20	.05	.06	.03

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. Because baseline motives are person-level variables, EMA variables reported here are based on person-level aggregates to facilitate meaningful correlations.

Table 4

Descriptive statistics and correlations for measures analyzed in Aim 2

				Correlations														
Aim 2 measures	*M*	*SD*	*range*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Momentary substance use																			
1. Alcohol use	0.14	0.34	0 to 1																
2. Cannabis use	0.24	0.43	0 to 1	.21***															
3. Simultaneous use	0.08	0.27	0 to 1	.67***	.41***														
Momentary cannabis use motives																			
4. Coping-anxiety	1.98	1.19	1 to 5	-.04	--	.00													
5. Coping-depression	1.72	1.13	1 to 5	.01	--	.05	.69***												
6. Social	1.73	1.17	1 to 5	.31***	--	.31***	.13***	.19***											
7. Enhancement	3.94	1.07	1 to 5	.03	--	.07*	.05*	.10***	.14***										
8. Conformity	1.15	0.55	1 to 5	.14***	--	.16***	.06*	.08**	.39***	-.05*									
9. Expansion	2.20	1.19	1 to 5	-.00	--	.02	.12***	.16***	.11***	.23***	.15***								
10. Availability	2.69	1.34	1 to 5	-.06*	--	-.08**	-.13***	-.14***	.22***	.18***	.19***	.15***							
Momentary alcohol use motives																			
11. Coping-anxiety	1.63	1.02	1 to 5	--	.04	.04	.61***	.59***	.31***	.09	.13**	.11*	.05						
12. Coping-depression	1.48	0.97	1 to 5	--	.06	.07***	.61***	.75***	.32***	.08	.10*	.02	-.01	.70***					
13. Social	2.57	1.48	1 to 5	--	-.14***	-.12***	.27***	.25***	.82***	.19***	.38***	.11*	.38***	.31***	.24***				
14. Enhancement	3.69	1.14	1 to 5	--	.02	.01	.17***	.20***	.30***	.60***	-.03	.18***	.11*	.15***	.16***	.30***			
15. Conformity[a]	1.32	0.83	1 to 5	--	--	--	.13*	.04	.32***	-.03	.72***	.14**	.28***	.13**	.04	.42***	-0.05		
16. Expansion	1.84	1.84	1 to 5	--	.08*	.10**	.19***	.14**	.13**	.19***	.10	.75***	.21***	.15***	.13***	.14***	.25***	.10*	
17. Availability	2.63	2.63	1 to 5	--	-.09**	-.13***	-.07	-.05	.35***	-.00	.32***	.24***	.84***	.08*	.09*	.33***	.17***	.29***	.27***

* $p < .05$, ** $p < .01$, *** $p < .001$

[a]The conformity motive item for alcohol use was inadvertently left out of the EMA protocol when participants reported only using alcohol (and not cannabis). Thus, correlations for alcohol conformity motives with cannabis and simultaneous use could not be computed.

Table 5

Descriptive statistics and correlations for measures analyzed in Aim 3

				Correlations														
Aim 3 measures	*M*	*SD*	*range*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Momentary alcohol use motives																		
1. Coping-anxiety	1.63	1.02	1 to 5															
2. Coping-depression	1.48	0.97	1 to 5	.71***														
3. Enhancement	3.69	1.14	1 to 5	.15***	.16***													
Momentary cannabis use motives																		
4. Coping-anxiety	1.98	1.19	1 to 5	.61***	.31***	.17***												
5. Coping-depression	1.72	1.13	1 to 5	.59***	.75***	.20***	.69***											
6. Enhancement	3.94	1.07	1 to 5	.09	.08	.60***	.05*	.10***										
Momentary substance use																		
7. Alcohol use	0.14	0.34	0 to 1	--	--	--	-.04	.01	.03									
8. Cannabis use	0.24	0.43	0 to 1	.04	.06	.02	--	--	--	.21***								
9. Simultaneous use	0.08	0.27	0 to 1	04	.07	.01	.00	.05	.07*	.67***	.41***							
Momentary subjective appraisals																		
10. Drinking-contingent relief	2.20	1.35	1 to 5	.48***	.50***	.26***	.47***	.58***	.20***	--	.03	.03						
11. Drinking-contingent pleasure	3.64	1.11	1 to 5	.18***	.16***	.56***	.10	.21***	.36***	--	-.07*	-.07*	.34***					
12. Cannabis-contingent relief	2.75	1.36	1 to 5	.33***	.40***	.16**	.51***	.49***	.14***	-.03	--	.00	.65***	.23***				
13. Cannabis-contingent pleasure	4.07	0.99	1 to 5	.10*	.08	.50***	.17***	.12***	.56***	.02	--	.04	.26***	.46***	.31***			
Momentary affective states																		
14. Anxious mood	1.31	0.64	1 to 5	.39***	.37***	.02	.22***	.26***	.03	-.02	-.01	-.02	.24***	.01	.10***	-.06*		
15. Depressed mood	1.17	0.45	1 to 5	.30***	.43***	-.06	.20***	.38***	-.06*	-.00	-.00	-.00	.17***	-.08*	.13***	-.11***	.62***	
16. Positive mood	2.33	0.81	1 to 5	-.01	-.05	.37***	.00	.00	.33***	.17***	.13***	.13	.20***	.36***	.23***	.41***	-.16***	-.13***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 6

Aim 1 results from Models 1 through 3 examining whether baseline drinking motives interact with daily-life affect to predict ***momentary alcohol use***

	Model 1: Coping-anxiety × anxious mood			**Model 2: Coping-depression × depressed mood**			**Model 3: Enhancement × positive mood**		
Effect	*OR*	*95% CI*	*p*	*OR*	*95% CI*	*p*	*OR*	*95% CI*	*p*
Intercept	**0.00**	**[0.00, 0.01]**	**<.001**	**0.00**	**[0.00, 0.01]**	**<.001**	**0.00**	**[0.00, 0.01]**	**<.001**
Cumulative-average mood	0.82	[0.53, 1.28]	.360	0.60	[0.33, 1.07]	.077	**2.16**	**[1.58, 2.95]**	**<.001**
Baseline motive	0.97	[0.69, 1.36]	.867	0.98	[0.63, 1.51]	.926	1.07	[0.80, 1.42]	.596
Cumulative-average mood × Motive	0.86	[0.51, 1.44]	.556	1.09	[0.61, 1.93]	.777	1.23	[0.86, 1.77]	.250
Covariates									
Momentary mood	**0.66**	**[0.50, 0.89]**	**.006**	**0.68**	**[0.49, 0.96]**	**.026**	**2.13**	**[1.69, 2.68]**	**<.001**
Person-level mood	**3.31**	**[0.69, 1.36]**	**.012**	**4.13**	**[1.41, 12.09]**	**.010**	**1.83**	**[1.20, 2.80]**	**.006**
Momentary cannabis use	**3.23**	**[2.57, 4.07]**	**<.001**	**3.22**	**[2.56, 4.06]**	**<.01**	**2.87**	**[2.27, 3.63]**	**<.001**
Hour after wake	**1.32**	**[1.27, 1.36]**	**<.001**	**1.32**	**[1.27, 1.36]**	**<.001**	**1.30**	**[1.26, 1.35]**	**<.001**
Weekend	**2.61**	**[2.00, 3.41]**	**<.001**	**2.62**	**[2.00, 3.41]**	**<.001**	**2.57**	**[1.97, 3.36]**	**<.001**
Study day	0.99	[0.96, 1.03]	.664	0.99	[0.96, 1.03]	.755	0.99	[0.96, 1.03]	.755
Age	1.03	[0.99, 1.06]	.158	1.03	[0.99, 1.06]	.152	1.03	[0.99, 1.07]	.149
Male (ref=female or nonbinary)	1.10	[0.67, 1.79]	.708	1.06	[0.65, 1.73]	.803	1.13	[0.69, 1.87]	.620

Note. OR = odds ratio. *95% CI* = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 7

Aim 1 results from Models 4 and 5 examining whether baseline cannabis use motives interact with daily-life affect to predict momentary cannabis use

	Model 4: Coping × negative mood			**Model 5: Enhancement × positive mood**		
Effect	*OR*	*95% CI*	*p*	*OR*	*95% CI*	*p*
Intercept	**0.14**	**[0.10, 0.19]**	**<.001**	**0.14**	**[0.10, 0.19]**	**<.001**
Cumulative-average mood	1.07	[0.80, 1.45]	.732	1.05	[0.89, 1.24]	.531
Baseline motive	1.20	[0.89, 1.60]	.226	**1.49**	**[1.11, 2.01]**	**.008**
Cumulative-average mood × Motive	0.81	[0.62, 1.07]	.133	1.07	[0.84, 1.36]	.577
Covariates						
Momentary mood	**0.66**	**[0.50, 0.87]**	**.003**	**2.93**	**[2.48, 3.47]**	**<.001**
Person-level mood	1.08	[0.39, 3.00]	.875	0.82	[0.56, 1.21	.316
Momentary alcohol use	**2.38**	**[1.98, 2.87]**	**<.001**	**2.17**	**[1.79, 2.63]**	**<.001**
Hour after wake	**1.08**	**[1.06, 1.10]**	**<.001**	**1.08**	**[1.06, 1.10]**	**<.001**
Weekend	**1.27**	**[1.09, 1.48]**	**.002**	**1.29**	**[1.10. 1.51]**	**.001**
Study day	**0.98**	**[0.96, 1.00]**	**.016**	**0.98**	**[0.96, 1.00]**	**.018**
Age	1.02	[0.99, 1.05]	.211	1.03	[1.00, 1.06]	.093
Male (ref=female or nonbinary)	1.12	[0.72, 1.73]	.608	0.98	[0.63, 1.54]	.942

Note. OR = odds ratio. 95% CI = 95% confidence interval. Significant effects at p < .05 are bolded.

Table 8

Aim 1 results from Models 6 and 7 examining whether baseline motives for simultaneous alcohol and cannabis use interact with daily-life affect to predict ***momentary simultaneous use*** *compared to alcohol or cannabis use alone*

	Model 6: Coping × negative mood			**Model 7: Positive effects × positive mood**		
	OR	*95% CI*	*p*	*OR*	*95% CI*	*p*
Effect	Predicting simultaneous use (compared to using *cannabis* alone)					
Intercept	**0.06**	**[0.03, 0.10]**	**<.001**	**0.07**	**[0.04, 0.12]**	**<.001**
Cumulative-average mood	0.70	[0.40, 1.24]	.220	**2.04**	**[1.47, 2.82]**	**<.001**
Baseline motive	1.09	[0.89, 1.33]	.397	1.01	[0.81, 1.25]	.945
Cumulative-average mood × Motive	0.95	[0.56, 1.61]	.861	0.94	[0.68, 1.30]	.720
Covariates						
Momentary mood	0.98	[0.51, 1.88]	.958	1.44	[0.98, 2.13]	.066
Person-level mood	2.10	[0.84, 5.27]	.112	1.13	[0.75, 1.70]	.552
Hour after wake	**1.18**	**[1.14, 1.23]**	**<.001**	**1.18**	**[1.13, 1.22]**	**<.001**
Weekend	**1.91**	**[1.42, 2.58]**	**<.001**	**1.85**	**[1.38, 2.49]**	**<.001**
Study day	1.00	[0.96, 1.03]	.847	1.00	[0.97, 1.04]	.936
Age	**1.04**	**[1.01, 1.08]**	**.022**	**1.04**	**[1.01, 1.08]**	**.018**
Male (ref=female or nonbinary)	1.17	[0.73, 1.87]	.509	1.20	[0.75, 1.92]	.452
	Predicting simultaneous use (compared to using *alcohol* alone)					
Intercept	0.64	[0.33, 1.25]	.186	0.65	[0.33, 1.28]	.209
Cumulative-average mood × Motive	1.32	[0.69, 2.52]	.401	1.07	[0.77, 1.55]	.702
Baseline motive	1.05	[0.83, 1.32]	.669	0.94	[0.74, 1.19]	.288
Cumulative-average mood × Motive	0.91	[0.50, 1.65]	.756	0.77	[0.54, 1.10]	.146
Covariates						
Momentary mood	1.75	[0.81, 3.79]	.153	**1.55**	**[1.00, 2.40]**	**.048**
Person-level mood	1.17	[0.41, 3.38]	.763	**0.61**	**[0.39, 0.97]**	**.036**
Hour after wake	1.03	[0.99, 1.07]	.190	1.03	[0.99, 1.08]	.155
Weekend	0.91	[0.66, 1.25]	.547	0.90	[0.65, 1.23]	.487
Study day	0.97	[0.94, 1.01]	.157	0.97	[0.94, 1.01]	.186
Age	**1.06**	**[1.02, 1.11]**	**.004**	**1.06**	**[1.02, 1.11]**	**.004**
Male (ref=female or nonbinary)	1.27	[0.73, 2.22]	.386	1.18	[0.68, 2.04]	.557

Note. OR = odds ratio. *95% CI* = 95% confidence interval. Significant effects at $p < .05$ are bolded. The top and bottom half of this table represent effects from the same multinomial logistic models with the reference group for the multinomial outcome switched from cannabis use alone (top half of the table) to alcohol use alone (bottom half of the table).

Table 9

Aim 2 results from Models 8 through 14 examining whether momentary cannabis use motives depend on simultaneous alcohol use

	Model 8: Coping-anxiety			**Model 9: Coping-depression**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**2.39**	**[2.00, 2.77]**	**<.001**	**1.81**	**[1.42, 2.20]**	**<.001**
Simultaneous alcohol use	0.01	[-0.14, 0.16]	.912	-0.00	[-0.14, 0.14]	.977
Covariates						
Person-level alcohol use	-0.59	[-1.49, 0.31]	.195	-0.04	[-0.97, 0.89]	.930
Presence of others	0.00	[-0.11, 0.11]	.964	-0.03	[-0.11, 0.05]	.523
Hour after wake	-0.01	[-0.02, 0.00]	.075	-0.00	[-0.01, 0.01]	.631
Weekend	**-0.17**	**[-0.26, -0.08]**	**<.001**	-0.03	[-0.10, 0.03]	.342
Study day	**-0.01**	**[-0.01, 0.05]**	**.005**	0.00	[-0.01, 0.01]	.906
Age	0.02	[-0.01, 0.05]	.246	0.00	[-0.03, 0.04]	.876
Male (ref=female or nonbinary)	-0.14	[-0.58, 0.29]	.508	-0.09	[-0.54, 0.36]	.699
	Model 10: Social			**Model 11: Enhancement**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**1.19**	**[0.89, 1.50]**	**<.001**	**3.92**	**[3.59, 4.27]**	**<.001**
Simultaneous alcohol use	**0.68**	**[0.46, 0.89]**	**<.001**	0.07	[-0.03, 0.17]	.169
Covariates						
Person-level alcohol use	**1.05**	**[0.32, 1.79]**	**.006**	-0.23	[-0.97, 0.51]	.533
Presence of others	**0.40**	**[0.28, 0.52]**	**<.001**	0.00	[-0.10, 0.11]	.986
Hour after wake	0.01	[-0.00, 0.02]	.115	-0.00	[-0.01, 0.01]	.839
Weekend	0.01	[-0.09, 0.10]	.905	-0.01	[-0.10, 0.07]	.771
Study day	**-0.02**	**[-0.03, -0.00]**	**.006**	-0.01	[-0.02, 0.00]	.071
Age	**-0.03**	**[-0.05, -0.00]**	**.024**	-0.01	[-0.03, 0.01]	.593
Male (ref=female or nonbinary)	-0.02	[-0.34, 0.30]	.893	0.27	[-0.09, 0.62]	.145
	Model 12: Conformity			**Model 13: Expansion**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**1.01**	**[0.89, 1.13]**	**<.001**	**2.41**	**[2.02, 2.80]**	**<.001**
Simultaneous alcohol use	**0.25**	**[0.10, 0.40]**	**.001**	**0.12**	**[0.03, 0.22]**	**.014**
Covariates						
Person-level alcohol use	0.11	[-0.18, 0.41]	.451	-0.61	[-1.50, 0.28]	.176
Presence of others	**0.08**	**[0.02, 0.14]**	**.007**	**-0.13**	**[-0.23, -0.03]**	**.010**
Hour after wake	0.00	[-0.00, 0.01]	.418	-0.00	[-0.01, 0.01]	.681
Weekend	0.05	[-0.00, 0.09]	.068	-0.05	[-0.13, 0.03]	.228
Study day	0.00	[-0.00, 0.01]	.471	**0.03**	**[0.02, 0.04]**	**<.001**
Age	**-0.01**	**[-0.02, -0.00]**	**.010**	-0.00	[-0.04, 0.03]	.824
Male (ref=female or nonbinary)	-0.03	[-0.14, 0.08]	.591	-0.33	[-0.77, 0.11]	.136
	Model 14: Availability					
Effect	*b*	*95% CI*	*p*			
Intercept	**2.85**	**[2.42, 3.27]**	**<.001**			
Simultaneous alcohol use	0.09	[-0.02, 0.19]	.105			
Covariates						
Person-level alcohol use	-0.22	[-1.20, 0.76]	.658			
Presence of others	**-0.12**	**[-0.23, -0.01]**	**.029**			
Hour after wake	0.01	[-0.00, 0.02]	.251			
Weekend	-0.02	[-0.11, 0.07]	.674			
Study day	**0.02**	**[0.00, 0.03]**	**.004**			
Age	**-0.05**	**[-0.09, -0.02]**	**.005**			
Male (ref=female or nonbinary)	-0.16	[-0.64, 0.32]	.515			

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 10

Aim 2 results from Models 15 through 20 examining whether momentary alcohol use motives depend on simultaneous cannabis use

	Model 15: Coping-anxiety			**Model 16: Coping-depression**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**1.60**	**[1.22, 1.97]**	**<.001**	**1.38**	**[1.03, 1.74]**	**<.001**
Simultaneous cannabis use	0.10	[-0.06, 0.26]	.235	0.08	[-0.08, 0.24]	.331
Covariates						
Person-level cannabis use	-0.01	[-0.53, 0.52]	.983	0.18	[-0.34, 0.70]	.495
Presence of others	-0.06	[-0.22, 0.11]	.513	-0.14	[-0.28, 0.00]	.056
Hour after wake	-0.00	[-0.02, 0.01]	.575	0.00	[-0.01, 0.01]	.909
Weekend	**-0.12**	**[-0.24, 0.01]**	**.032**	-0.09	[-0.19, 0.00]	.063
Study day	**0.02**	**[0.01, 0.03]**	**.005**	**0.02**	**[0.01, 0.03]**	**<.001**
Age	-0.00	[-0.03, 0.02]	.841	0.00	[-0.02, 0.03]	.693
Male (ref=female or nonbinary)	-0.12	[-0.44, 0.20]	.452	-0.13	[-0.45, 0.19]	.411
	Model 17: Social			**Model 18: Enhancement**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**2.09**	**[1.56, 2.63]**	**<.001**	**3.25**	**[2.78, 3.71]**	**<.001**
Simultaneous cannabis use	**0.20**	**[0.03, 0.37]**	**.020**	0.12	[-0.01, 0.26]	.078
Covariates						
Person-level cannabis use	-0.50	[-1.26, 0.26]	.193	-0.09	[-0.77, 0.58]	.780
Presence of others	**0.67**	**[-0.46, 0.89]**	**<.001**	0.07	[-0.11, 0.24]	.447
Hour after wake	0.00	[-0.02, 0.02]	.738	**0.02**	**[0.01, 0.04]**	**.007**
Weekend	**0.15**	**[0.01, 0.30]**	**.039**	-0.05	[-0.16, 0.07]	.446
Study day	0.01	[-0.01, 0.02]	.462	0.00	[-0.01, 0.02]	.641
Age	**-0.06**	**[-0.10, -0.02]**	**.001**	-0.03	[-0.06, 0.00]	.052
Male (ref=female or nonbinary)	-0.16	[-0.63, 0.30]	.494	0.12	[-0.30, 0.53]	.575
	Model 19: Expansion			**Model 20: Availability**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**1.53**	**[1.07, 1.98]**	**<.001**	**2.66**	**[2.14, 3.16]**	**<.001**
Simultaneous cannabis use	**0.15**	**[0.03, 0.27]**	**.013**	0.13	[-0.05, 0.31]	.163
Covariates						
Person-level cannabis use	0.30	[-0.37, 0.97]	.377	-0.15	[-0.88, 0.59]	.691
Presence of others	-0.11	[-0.26, 0.05]	.179	0.01	[-0.17, 0.19]	.890
Hour after wake	0.01	[-0.00, 0.03]	.062	-0.00	[-0.02, 0.01]	.679
Weekend	0.03	[-0.07, 0.14]	.535	-0.08	[-0.21, 0.04]	.177
Study day	**0.02**	**[0.01, 0.04]**	**<.001**	**0.03**	**[0.01, 0.04]**	**<.001**
Age	-0.03	[-0.06, 0.01]	.109	**-0.05**	**[-0.09, -0.01]**	**.004**
Male (ref=female or nonbinary)	-0.29	[-0.70, 0.13]	.076	-0.18	[-0.63, 0.28]	.442

Note. *95% CI* = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 11

Aim 3 results from Models 21 and 22 examining whether momentary simultaneous cannabis use moderates the associations between coping alcohol motives and drinking-contingent relief

	Model 21: Coping-anxiety			**Model 22: Coping-depression**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**2.35**	**[1.93, 2.76]**	**<.001**	**2.49**	**[2.07, 2.90]**	**<.001**
Momentary coping motive	**0.39**	**[0.24, 0.55]**	**<.001**	**0.42**	**[0.26, 0.57]**	**<.001**
Simultaneous cannabis use	0.07	[-0.07, 0.22]	.319	0.07	[-0.08, 0.22]	.365
Coping motive × simultaneous use	**-0.26**	**[-0.45, -0.07]**	**.007**	-0.12	[-0.32, 0.08]	.224
Covariates						
Person-level coping motive	**0.97**	**[0.66, 1.28]**	**<.001**	**0.84**	**[0.52, 1.17]**	**<.001**
Person-level cannabis use	-0.26	[-0.87, 0.35]	.403	-0.43	[-1.05, 0.18]	.166
Baseline coping motive[a]	0.02	[-0.25, 0.29]	.898	0.15	[-0.25, 0.54]	.460
Hour after wake	-0.00	[-0.02, 0.01]	.761	-0.01	[-0.02, 0.01]	.507
Weekend	-0.02	[-0.15, 0.10]	.729	-0.03	[-0.16, 0.10]	.664
Study day	0.00	[-0.02, 0.02]	.975	-0.00	[-0.02, 0.01]	.971
Age	0.01	[-0.02, 0.03]	.676	0.00	[-0.03, 0.03]	.928
Male (ref=female or nonbinary)	-0.24	[-0.59, 0.12]	.196	-0.27	[-0.64, 0.10]	.158

[a]The baseline coping motive in model 21 is coping-anxiety and the baseline coping motive in model 22 is coping-depression, both from the Modified DMQ-R (Grant et al., 2007).

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 12

Aim 3 results from Models 23 and 24 examining whether momentary simultaneous cannabis use moderates the associations between coping alcohol motives and change in negative affect

	Model 23: Coping-anxiety predicting change in anxious mood			**Model 24: Coping-depression predicting change in depressed mood**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**0.98**	**[0.81, 1.14]**	**<.001**	**0.94**	**[0.79, 1.09]**	**<.001**
Momentary coping motive	**0.20**	**[0.12, 0.29]**	**<.001**	**0.26**	**[-0.92, -0.79]**	**<.001**
Simultaneous cannabis use	0.03	[-0.04, 0.09]	.414	-0.02	[-0.08, 0.03]	.411
Coping motive × simultaneous use	**-0.11**	**[-0.19, -0.02]**	**.016**	**-0.14**	**[-0.23, -0.05]**	**.003**
Covariates						
Last-prompt mood[a]	**-0.83**	**[-0.89, -0.78]**	**<.001**	**-0.85**	**[-0.92, -0.79]**	**<.001**
Person-level coping motive	**0.14**	**[0.05, 0.24]**	**.005**	**0.15**	**[0.06, 0.24]**	**.002**
Person-level cannabis use	0.03	[-0.17, 0.23]	.793	0.03	[-0.14, 0.21]	.702
Baseline coping motive[b]	0.04	[-0.04, 0.13]	.320	0.06	[-0.05, 0.17]	.289
Hour after wake	0.00	[-0.00, 0.01]	.468	0.00	[-0.00, 0.01]	.567
Weekend	-0.02	[-0.08, 0.03]	.340	0.02	[-0.04, 0.05]	.987
Study day	**0.01**	**[0.00, 0.01]**	**.041**	0.00	[-0.00, 0.01]	.050
Age	-0.00	[-0.01, 0.01]	.437	0.00	[-0.01, 0.01]	.853
Male (ref=female or nonbinary)	-0.04	[-0.16, 0.07]	.447	0.05	[-0.13, 0.08]	.671

[a]Last-prompt mood is anxious mood for model 23 and depressed mood for model 24.

[b]The baseline coping motive in model 23 is coping-anxiety and the baseline coping motive in model 24 is coping-depression, both from the Modified DMQ-R (Grant et al., 2007).

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 13

Aim 3 results from Model 25 examining whether momentary simultaneous cannabis use moderates the association between enhancement alcohol motives and drinking-contingent pleasure

	Model 25: Enhancement		
Effect	*b*	*95% CI*	*p*
Intercept	**3.87**	**[3.56, 4.19]**	**<.001**
Momentary enhancement motive	**0.49**	**[0.36, 0.61]**	**<.001**
Simultaneous cannabis use	-0.03	[-0.15, 0.10]	.665
Enhancement motive × simultaneous use	**-0.34**	**[-0.50, -0.18]**	**<.001**
Covariates			
Person-level enhancement motive	**0.63**	**[0.47, 0.78]**	**<.001**
Person-level cannabis use	-0.37	[-0.82, 0.09]	.111
Baseline enhancement motive[a]	-0.05	[-0.21, 0.12]	.577
Hour after wake	0.00	[-0.01, 0.01]	.833
Weekend	-0.04	[-0.14, 0.07]	.495
Study day	**-0.01**	**[-0.03, -0.00]**	**.026**
Age	-0.01	[-0.03, 0.01]	.353
Male (ref=female or nonbinary)	0.07	[-0.20, 0.34]	.610

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 14

Aim 3 results from Model 26 examining whether momentary simultaneous cannabis use moderates the association between enhancement alcohol motives and change in positive affect

	Model 26: Enhancement		
Effect	*b*	*95% CI*	*p*
Intercept	**2.04**	**[1.75, 2.33]**	**<.002**
Momentary enhancement motive	**0.08**	**[0.01, 0.15]**	**.030**
Simultaneous cannabis use	**0.11**	**[0.01, 0.20]**	**.023**
Enhancement motive × simultaneous use	-0.00	[-0.10, 0.10]	.953
Covariates			
Last-prompt positive mood	**-0.69**	**[-0.75, -0.63]**	**<.001**
Person-level enhancement motive	**0.29**	**[0.17, 0.40]**	**<.001**
Person-level cannabis use	-0.29	[-0.63, 0.04]	.086
Baseline enhancement motive	-0.12	[-0.24, 0.00]	.052
Hour after wake	-0.00	[-0.01, 0.01]	.759
Weekend	0.01	[-0.06, 0.09]	.739
Study day	-0.01	[-0.02, 0.00]	.142
Age	-0.00	[-0.02, 0.01]	.704
Male (ref=female or nonbinary)	-0.12	[-0.31, 0.08]	.231

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 15

Aim 3 results from Models 27 and 28 examining whether momentary simultaneous alcohol use moderates the associations between coping cannabis motives and cannabis-contingent relief

	Model 27: Coping-anxiety			**Model 28: Coping-depression**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**2.90**	**[2.57, 3.24]**	**<.001**	**3.06**	**[2.71, 3.40]**	**<.001**
Momentary coping motive	**0.32**	**[0.21, 0.42]**	**<.001**	**0.31**	**[0.21, 0.41]**	**<.001**
Simultaneous alcohol use	-0.03	[-0.15, 0.08]	.602	-0.03	[-0.15, 0.09]	.619
Coping motive × simultaneous use	-0.11	[-0.25, 0.04]	.142	-0.14	[-0.31, 0.03]	.108
Covariates						
Person-level coping motive	**0.70**	**[0.49, 0.91]**	**<.001**	**0.64**	**[0.43, 0.86]**	**<.001**
Person-level alcohol use	-0.37	[-1.13, 0.39]	.339	-0.67	[-1.45, 0.12]	.096
Baseline coping motive[a]	0.00	[-0.23, 0.24]	.972	-0.01	[-0.26, 0.24]	.954
Hour after wake	-0.00	[-0.01, 0.01]	.714	-0.00	[-0.02, 0.01]	.409
Weekend	0.04	[-0.05, 0.14]	.382	0.00	[-0.10, 0.10]	.932
Study day	-0.00	[-0.01, 0.01]	.730	-0.01	[-0.02, 0.01]	.355
Age	0.02	[-0.01, 0.05]	.187	0.03	[-0.00, 0.05]	.072
Male (ref=female or nonbinary)	-0.26	[-0.62, 0.11]	.164	-0.29	[-0.67, 0.08]	.126

[a]The baseline coping motive in model 27 is coping-anxiety and the baseline coping motive in model 28 is coping-depression, both from the Modified DMQ-R (Grant et al., 2007).

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 16

Aim 3 results from Models 29 and 30 examining whether momentary simultaneous alcohol use moderates the associations between coping cannabis motives and change in negative affect

	Model 29: Coping-anxiety predicting change in anxious mood			**Model 30: Coping-depression predicting change in depressed mood**		
Effect	*b*	*95% CI*	*p*	*b*	*95% CI*	*p*
Intercept	**1.01**	**[0.88, 1.13]**	**<.001**	**0.88**	**[0.77, 0.98]**	**<.001**
Momentary coping motive	**0.09**	**[0.03, 0.15]**	**.004**	**0.10**	**[0.03, 0.17]**	**.006**
Simultaneous alcohol use	-0.01	[-0.06, 0.05]	.779	-0.03	[-0.06, 0.01]	.193
Coping motive × simultaneous use	0.04	[-0.03, 0.11]	.292	-0.01	[-0.08, 0.06]	.789
Covariates						
Last-prompt mood[a]	**-0.81**	**[-0.86, -0.76]**	**<.001**	**-0.76**	**[-0.81, -0.71]**	**<.001**
Person-level coping motive	0.00	[-0.06, 0.06]	.920	**0.06**	**[0.01, 0.11]**	**.023**
Person-level alcohol use	0.12	[-0.10, 0.35]	.284	0.02	[-0.16, 0.20]	.833
Baseline coping motive[b]	**0.13**	**[0.06, 0.19]**	**<.001**	**0.08**	**[0.02, 0.14]**	**.006**
Hour after wake	0.00	[-0.01, 0.01]	.830	-0.00	[-0.01, 0.00]	.433
Weekend	0.03	[-0.00, 0.08]	.154	0.03	[-0.00, 0.06]	.061
Study day	0.00	[-0.00, 0.01]	.481	0.00	[-0.00, 0.01]	.260
Age	-0.01	[-0.01, 0.00]	.106	-0.00	[-0.01, 0.01]	.814
Male (ref=female or nonbinary)	-0.10	[-0.20, 0.00]	.058	-0.03	[-0.12, 0.05]	.413

[a]Last-prompt mood is anxious mood for model 29 and depressed mood for model 30.

[b]The baseline coping motive in model 29 is coping-anxiety and the baseline coping motive in model 30 is coping-depression, both from the Modified DMQ-R (Grant et al., 2007).

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 17

Aim 3 results from Model 31 examining whether momentary simultaneous alcohol use moderates the association between enhancement cannabis motives and cannabis-contingent pleasure

	Model 31: Enhancement		
Effect	*b*	*95% CI*	*p*
Intercept	**4.19**	**[3.99, 4.39]**	**<.001**
Momentary enhancement motive	**0.37**	**[0.27, 0.46]**	**<.001**
Simultaneous alcohol use	-0.02	[-0.10, 0.07]	.688
Enhancement motive × simultaneous use	-0.00	[-0.12, 0.12]	.948
Covariates			
Person-level enhancement motive	**0.72**	**[0.57, 0.87]**	**<.001**
Person-level alcohol use	-0.17	[-0.62, 0.28]	.449
Baseline enhancement motive	-0.04	[-0.21, 0.14]	.685
Hour after wake	0.00	[-0.00, 0.01]	.370
Weekend	-0.04	[-0.11, 0.04]	.325
Study day	**-0.02**	**[-0.02, -0.01]**	**<.001**
Age	0.00	[-0.01, 0.02]	.615
Male (ref=female or nonbinary)	-0.03	[-0.24, 0.18]	.762

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

Table 18

Aim 3 results from Model 32 examining whether momentary simultaneous alcohol use moderates the association between enhancement cannabis motives and change in positive affect

	Model 32: Enhancement		
Effect	*b*	*95% CI*	*p*
Intercept	**1.92**	**[1.72, 2.13]**	**<.001**
Momentary enhancement motive	**0.12**	**[0.08, 0.17]**	**<.001**
Simultaneous alcohol use	**0.08**	**[0.01, 0.16]**	**.030**
Enhancement motive × simultaneous use	-0.02	[-0.12, 0.07]	.600
Covariates			
Last-prompt positive mood	**-0.66**	**[-0.71, -0.61]**	**<.001**
Person-level enhancement motive	**0.23**	**[0.10, 0.36]**	**<.001**
Person-level alcohol use	0.06	[-0.31, 0.43]	.740
Baseline enhancement motive	0.02	[-0.12, 0.17]	.755
Hour after wake	-0.00	[-0.01, 0.00]	.231
Weekend	-0.03	[-0.10, 0.03]	.281
Study day	**-0.01**	**[-0.02, -0.00]**	**.001**
Age	-0.00	[-0.01, 0.01]	.842
Male (ref=female or nonbinary)	-0.12	[-0.29, 0.06]	.189

Note. 95% CI = 95% confidence interval. Significant effects at $p < .05$ are bolded.

VITA

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