Smoke, Sip, Sleep, Repeat: Investigating Daily-Level Bidirectional Relationships Between Separate and Simultaneous Alcohol-Cannabis Use and Sleep

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Abstract

Objective: Many young adults use alcohol and cannabis to regulate sleep. Given the high prevalence of simultaneous alcohol-cannabis use in this population, there is a need to clarify the association between simultaneous use and sleep. This study examined daily relationships between simultaneous use (versus cannabis-only, alcohol-only, and no use) and key sleep indices (i.e., subjective sleep quality, sleep duration, and bedtime), exploring the moderating role of substance use problem severity. **Method:** Young adults (N=150; 64% female; M_{age} = 22.09) completed daily morning surveys in a smartphone app assessing prior-day alcohol and cannabis use, as well as sleep indices for the previous night. Participants also completed measures of alcohol and cannabis problem severity at baseline. **Results:** Compared to simultaneous use days, participants reported worse sleep quality and shorter sleep duration on alcohol-only days, earlier bedtime on cannabis-only days, and poorer sleep quality and earlier bedtime on no-use days. Further, individuals with greater alcohol problem severity reported shorter sleep durations on alcohol-only and cannabis-only days than simultaneous use days, as well as later bedtimes on alcohol-only versus simultaneous use days. By contrast, those with lower alcohol problem severity reported earlier bedtimes on no-use days and alcohol-only days compared to simultaneous use days. Cannabis problem severity did not moderate any day-level associations, and sleep outcomes were not significantly associated with likelihood of engaging in next-day simultaneous use. **Conclusion:** Findings illuminate the daily-level relationships between simultaneous alcohol-cannabis use and sleep. Future research should explore tailoring sleep interventions based on simultaneous use behavior.

Keywords: cannabis; alcohol; co-use; sleep; ecological momentary assessment

Public Health Significance: Using both alcohol and cannabis on the same day is associated with different sleep outcomes than using either substance on its own, and these differences may depend on severity of alcohol problems. Findings may inform interventions to address substance harms and improve sleep health among young adults.

Introduction

Simultaneous use of alcohol and cannabis (i.e. co-use of both substances close in time or with overlapping effects) is prevalent among young adults and is associated with greater quantity and frequency of consumption of both substances, as well as increased substance-related consequences (for reviews, see Lee et al., 2022). Research indicates some people are motivated to use cannabis and alcohol simultaneously to improve sleep outcomes (Patrick et al., 2018; Waddell et al., 2023). This is unsurprising, as cannabis and alcohol each have a long history of being used as sleep aids (see Babson & Bonn-Miller, 2014; Johnson et al., 1998). Despite some recent research on the relationship between simultaneous use and sleep (i.e., Graupensperger et al., 2021; Sznitman et al., 2023a; Sznitman et al., 2023b; Wycoff, Miller, & Trull, 2024), findings have been mixed and associations remain unclear. The goal of the current study was to clarify associations between simultaneous alcohol-cannabis use and sleep among young adults, exploring the potential moderating role of severity of alcohol and cannabis problems.

Cannabis Use, Alcohol Use and Sleep

Data from both clinical trials and observational studies suggest that cannabis use is often associated with short-term improvements in sleep compared to non-use, particularly in self-reported sleep quality (Babson & Bonn-Miller, 2014; Tervo-Clemmens et al., 2023). Proposed mechanisms include modulation of the endocannabinoid system, leading to the release of neurotransmitters such as serotonin, which facilitate sleep initiation and maintenance (Babson et al., 2017). In contrast, poorer sleep outcomes have been observed among those seeking treatment for cannabis use (Pacek et al., 2017). Further, between-person studies find higher rates of insomnia and worse sleep quality among those who use cannabis more frequently compared to those who engage in less frequent use (Conroy et al., 2016), and withdrawal is consistently

associated with disturbed sleep lasting weeks (Babson & Bonn-Miller, 2014; Budney et al., 2004). Findings on sleep duration may vary by study design: nationwide cross-sectional research has linked daily (versus less frequent) cannabis use to both shorter and longer sleep durations (compared to average sleep durations; Gonzales et al., 2023), whereas within-person research among those with a history of cannabis use finds longer sleep duration on cannabis use nights compared to non-use nights (Campbell et al., 2020). Evidence concerning bedtime is mixed, with some within-person research finding an association between later bedtime and increased likelihood of use (Troxel et al., 2021) and other research finding no association between bedtime and frequency and quantity of use (Winiger et al., 2021). Although factors such as potency and form of cannabis may help explain mixed findings, few studies examine these variables.

Among those who use alcohol, sleep effects also vary by frequency and heaviness of use. At low doses, alcohol can facilitate sleep onset by acting on gamma-aminobutyric acid (GABA) and adenosine activity (Chakravorty et al., 2016; Ebrahim et al., 2013), with polysomnographic evidence supporting reduced sleep onset latency (Garcia & Salloum, 2015). However, heavy and problematic alcohol use is tied to poorer sleep outcomes. Between-person studies link more frequent, heavier, and more problematic alcohol use to poorer overall sleep quality, shorter sleep duration, and more disturbances (Liu et al., 2021; Park et al., 2015), and review evidence confirms ties between problematic drinking, insomnia, and shortened sleep (Chakravorty et al., 2016). Sleep disturbance is particularly pronounced during withdrawal, reinforcing reliance on alcohol as a short-term sleep aid despite longer-term costs (Chakravorty et al., 2016; Smith et al., 2014). Within-person daily diary studies indicate that alcohol use predicts later bed and wake times (Fucito et al., 2018; Van Reen et al., 2016) and worse subjective sleep quality (Lydon et al., 2016), though effects on sleep duration are mixed.

In summary, the associations of cannabis and alcohol use with sleep outcomes are complex and mixed. Several between-person studies reveal that people who use these substances more (vs. less) heavily and frequently report worse sleep on average, while within-person daily diary studies highlight differences between use and non-use nights (e.g., longer sleep duration on cannabis use nights, later bedtimes and poorer quality on alcohol use nights). These mixed findings underscore the need for intensive longitudinal studies that examine the role of between-person differences in alcohol and cannabis problem severity when examining within-person (daily) associations between use and sleep. Further, research is needed to clarify these associations in the context of simultaneous use of alcohol and cannabis, which has received much less attention than single substance use.

Simultaneous Alcohol and Cannabis Use and Sleep

Daily diary studies are ideal for examining outcomes specific to simultaneous alcohol and cannabis use as they are able to isolate days of simultaneous use from days of single substance use to permit within-person comparisons (see Farrelly et al., 2025). To date, only four such studies have examined the daily-level impacts of simultaneous alcohol and cannabis use on sleep outcomes. One study of university students found shorter sleep onset latency and longer sleep duration after separate and simultaneous alcohol and cannabis use compared to abstinent nights (i.e. “no-use”; Sznitman et al., 2023b). However, alcohol-only nights were associated with more nightly awakenings than no-use and simultaneous use nights, while cannabis-only nights were linked to fewer early awakenings than no-use and simultaneous use nights (Sznitman et al., 2023b). Another daily diary study observed that individuals using cannabis for anxiety reported better sleep quality after simultaneous use and cannabis-only use compared to no-use and alcohol-only use, with cannabis-only use associated with the best sleep quality (Sznitman et al.,

2023a). Additionally, Graupensperger and colleagues (2021) found that, compared to abstinent days, participants reported worse perceived sleep quality on days when they consumed alcohol alone, better perceived sleep quality when they consumed cannabis alone, and conflicting evidence regarding simultaneous use. Specifically, participants reported both poorer perceived sleep health and fewer symptoms of insomnia following simultaneous compared to no-use days (Graupensperger et al., 2021). Finally, Wycoff and colleagues (2024) found that participants reported worse sleep quality following alcohol use, and that while cannabis-only use did not impact sleep outcomes, cannabis use attenuated alcohol's negative impact on sleep quality during simultaneous use. Overall, findings suggest cannabis may counteract some negative sleep effects of alcohol during simultaneous use, but results are mixed and further research is needed.

Surprisingly, little research to date has explored bidirectional relationships between simultaneous alcohol and cannabis use and sleep, despite research suggesting a prospective association between sleep disturbances and increased substance use and craving (e.g., Graupensperger et al., 2022; Troxel et al., 2022). Only one intensive longitudinal study to date has examined both the association between simultaneous use and same day sleep and the reverse association between sleep and next day simultaneous use (Wycoff, Miller, & Trull, 2024). This study found that longer sleep duration predicted greater next-day alcohol craving and cannabis use likelihood; however, sleep quality did not predict next-day cannabis or alcohol craving or likelihood of use at the daily level (Wycoff, Miller, & Trull, 2024).

In addition, none of the existing intensive longitudinal studies on the relationship between simultaneous use and sleep examine individual differences in the strength of this relationship as a function of the severity of alcohol and cannabis use problems. Problematic use severity is a multidimensional construct encompassing tolerance, psychological dependence,

withdrawal symptoms, functional impairment, and other substance-related difficulties (Adamson et al., 2010; Saunders et al., 1993), any of which may influence how simultaneous alcohol and cannabis use impacts sleep. As previously discussed, associations between alcohol or cannabis use and sleep may differ for those who use more heavily or are more dependent (Garcia & Salloum, 2015). It is thus important to examine the moderating role of problematic use severity to clarify mixed findings in prior research on associations between simultaneous use and sleep.

The Present Study

The present study aimed to examine the daily-level relationships between simultaneous alcohol and cannabis use and key sleep outcomes, including bedtime, sleep duration, and subjective sleep quality. We selected these outcomes because they are among the most consistently assessed parameters in prior daily diary studies of sleep (e.g., Graupensperger et al., 2021; Sznitman et al., 2023a), facilitating comparison with existing research. Drawing from prior ecological momentary assessment (EMA) research suggesting a general sleep-promoting effect of cannabis (Graupensperger et al., 2021; Sznitman et al., 2023a), we hypothesized that participants would report the best sleep outcomes on days when they used only cannabis relative to days when they engaged in no substance use or simultaneous alcohol and cannabis use. Conversely, given EMA findings indicating a negative relationship between alcohol-only use and sleep (Graupensperger et al., 2021; Sznitman et al., 2023a), we expected that days involving alcohol-only use would be associated with the poorest sleep outcomes relative to no substance use or simultaneous alcohol and cannabis use. Given that the amount of alcohol and cannabis consumed may differ across simultaneous and single substance use days, we conducted sensitivity analyses controlling for number of standard drinks consumed and amount of various forms of cannabis consumed.

We additionally hypothesized that individuals who use alcohol and cannabis heavily and problematically would report poorer sleep on average during the study, with individuals higher on alcohol problem severity experiencing the poorest sleep overall. With respect to moderation, we examined whether problem use severity moderated the within-person differences in sleep between simultaneous use versus single-substance use days. Given the lack of prior studies examining such moderation effects, analyses were treated as exploratory.

With respect to reverse associations, we hypothesized that poorer sleep nights would predict increased likelihood of next-day separate and simultaneous alcohol-cannabis use, given that individuals may be motivated to use substances to aid next-night sleep. However, given the lack of prior research on how sleep predicts next-day simultaneous use (Wycoff et al., 2024 was published after hypotheses were pre-registered), analyses examining how poor sleep relates to separate versus simultaneous alcohol-cannabis use were treated as exploratory. All hypotheses and analyses were preregistered on OSF on July 5, 2024 (Moore, 2025).

Method

Participants and Recruitment

This analysis utilizes baseline electronic daily diary data from a broader longitudinal Ecological Momentary Assessment (EMA) study examining simultaneous alcohol-cannabis use among young adults (Wardell et al., 2024). Though the larger study included 6- and 12-month follow-up EMAs, we analyzed only data from the baseline EMA period since this immediately followed assessment of alcohol and cannabis problem severity, two primary moderators in this study. Ethics approval for the broader study was granted by the ethics review boards at York University and the Centre for Addiction and Mental Health (CAMH) in Toronto, Canada.

Participants (N = 150) were young adults (64% female; M_{age} = 22.09, SD = 2.08) living in

Ontario, Canada who were of legal age to purchase both cannabis and alcohol and who reported co-using alcohol and cannabis (see Table 1 for demographics). This secondary analysis utilized all available data from participants enrolled in the parent study and so an a priori sample size determination was not conducted. Participants were recruited via online ads as well as posters distributed across university campuses and various community locations. Of the 177 participants that were initially enrolled in the study, $n = 9$ were excluded following baseline ($n = 2$ failed to meet cannabis/alcohol inclusion criteria, $n = 3$ were unable to verify Ontario residency, and $n = 4$ encountered technical issues preventing participation). Data from another $n = 17$ were excluded for poor survey compliance (< 10% of prompted surveys). One additional participant was excluded from analyses due to missing data on sex, which was a covariate in all models.

Inclusion criteria for the broader study were: (i) being between the ages of 19 and 25; (ii) consuming both alcohol and cannabis once per week or more over the past month; (iii) having at least two instances of simultaneous alcohol and cannabis use in the past month; and (iv) possessing a smartphone compatible with Android or iOS. Exclusion criteria were: (i) using any substances other than cannabis, alcohol, or nicotine once a month or more; (ii) undergoing current treatment for, or attempting to cut down on, cannabis or alcohol use; (iii) having a severe mental illness (for example, psychosis or mania) or a neurodevelopmental disorder; or (iv) using cannabis solely for medicinal purposes, as indicated by self-report.

Procedure

Following completion of an online screening survey, eligible individuals attended a baseline assessment (either in person or via videoconferencing). Participants first provided informed consent, and then downloaded the EMA application (MetricWire, Waterloo, Canada) onto their phones. Participants received training on EMA procedure, and were shown visual

instructional materials detailing how to accurately report their alcohol intake (in standard drink units) and their cannabis flower use (in grams). Following the training, participants completed an online questionnaire that captured demographic data and information related to alcohol and cannabis use, including severity of alcohol and cannabis problems (see Measures).

Participants commenced the EMA period on the day after the baseline assessment. Participants completed multiple smartphone surveys each day for 21 days, including a daily morning survey, two randomly timed surveys, and event-contingent surveys completed during substance use episodes. The present analyses utilized data from the daily morning surveys as they captured total consumption of alcohol and cannabis on a day-to-day basis (used as covariates) as well as key sleep indices from the night before (see EMA Measures below). Participants were instructed to complete the daily morning survey upon waking each morning, and the surveys were accessible in the app each day from 7:00 am to 2:00 pm, during which participants received multiple reminder notifications. Participants received a $40 gift card for the baseline session and between $45 to $115 in gift cards for the EMA (depending on compliance).

Baseline Measures

Demographics. The baseline survey assessed sex, gender, age, race and ethnicity, and other demographic variables collected to characterize the sample.

Cannabis Use Disorder Identification Test–Revised (CUDIT-R; Adamson et al., 2010). The CUDIT-R is an eight-item screening tool designed to detect hazardous cannabis use over the past six months. Items are rated on a 0 to 4 scale, with scores of 8 or above indicative of hazardous cannabis use and scores of 12 or above suggesting likelihood of a cannabis use disorder (CUD; Adamson et al., 2010).

Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993). The AUDIT

a 10-item screening instrument used to detect problematic alcohol use. The AUDIT was modified to assess the past 6 months for consistency with the CUDIT-R. The AUDIT is scored on a scale from 0 to 40, with scores of 8 indicative of hazardous drinking (Saunders et al., 1993).

EMA Measures

Alcohol Use. In each daily morning survey, participants were asked to report whether they had used any alcohol or drugs the previous day, and if so, to indicate how many standard drinks they had consumed. To assist in accurately reporting their consumption, participants had the option to refer to a visual standard drink conversion guide while answering these questions.

Cannabis Use. Participants who endorsed consuming cannabis the previous day were asked to indicate their method(s) of cannabis administration (i.e., smoking, vaporizing, ingesting, or other methods) along with the forms of cannabis products used (i.e., cannabis flower [referred to as "marijuana"], concentrates, edibles, cannabis beverages, or other forms). Follow-up questions assessed quantities of cannabis consumed in units of grams of flower, hits of concentrates, and servings of edibles/beverages. Items were adapted from the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (Cuttler & Spradlin, 2017).

Sleep Indices. At the beginning of each daily morning survey, participants were asked what time they went to sleep the previous night and what time they woke up that morning. Bedtime was reported on an ordinal scale with options including 0 = *before 9pm*, 1 = *9pm–9:59pm*, 2 = *10pm–10:59pm*, 3 = *11pm–11:59pm*, 4 = *12am–12:59am*, 5 = *1am–1:59am*, 6 = *2am–2:59am*, 7 = *3am or later*. Wake time was reported similarly, with response options ranging from 0 = *before 6am* to 8 = *1pm or later*. Participants' nightly total sleep time was determined by calculating number of hours between the midpoints of the sleep and wake time ranges indicated by participants in each daily morning survey. The outer categories were treated as one-hour

ranges for the purpose of assigning midpoints (e.g., *before 9pm* = 8:30pm; *3am or later* = 3:30am). Sleep quality was assessed using an item adapted from the Single-Item Sleep Quality Scale "*How would you rate your overall sleep quality last night? Consider how many hours you got, how well you fell and stayed asleep, and how refreshing your sleep was*," with response options ranging from 1 = *Terrible* to 5 = *Excellent* (Snyder et al., 2018).

Data Analysis

Prior to analyses, extreme outliers on the alcohol and cannabis quantity variables (i.e., *z* scores greater than 3.29 that were disconnected from the distribution; < 0.25% of all observations on each variable) were winsorized by replacing them with a value one point higher than the next-highest value. To examine the hypothesized day-level relationships between simultaneous use versus single substance use or no use and sleep indices, we specified a set of multilevel models wherein days (level 1) were nested within participants (level 2). We created separate models for each of the sleep outcome variables (i.e., bedtime, total sleep time, and sleep quality). The independent variable was represented as a set of three dummy-coded variables entered at level 1, each comparing simultaneous use days (i.e., days on which both alcohol and cannabis use were reported[1]; reference category) with no use, alcohol-only use, or cannabis-only use days. In post-hoc analyses, we reran each model with no-use days at the reference category in order to obtain estimates of differences in sleep outcomes between alcohol- and cannabis-only use days relative to no use days. To examine the moderating role of severity of alcohol and cannabis use problems, AUDIT and CUDIT-R scores were specified as level 2 predictors and were entered

[1] We defined simultaneous use broadly as same-day co-use of both alcohol and cannabis rather than restricting it to use within a shorter window. This approach accounts for situations—such as consuming edibles—where the effects of THC may persist for several hours. Of note, participants reported using alcohol and cannabis within the same 2 hours on 88.81% of co-use days, suggesting that same day co-use in this dataset likely reflects simultaneous use behavior a majority of the time.

into cross-level interactions with the level 1 dummy-coded substance use variables. Significant interactions were probed by examining the day-level associations between type of day (i.e., single-substance or no use vs. simultaneous use) and sleep outcomes conditioned on high and low values of AUDIT and CUDIT-R scores (one *SD* above and below the sample means, respectively). In models where a moderator did not interact with any of the dummy coded day type variables, interactions were trimmed to simplify interpretation of lower-order coefficients.

Additionally, to control for amounts of alcohol and cannabis consumed in sensitivity analyses, we conducted follow-up multilevel analyses comparing sleep indices on simultaneous use days vs. alcohol-only days controlling for number of standard drinks at level 1 (in models limited to days on which alcohol use occurred), as well as analyses comparing sleep on simultaneous use days vs. cannabis-only days controlling for grams of cannabis flower, number of edible and cannabis beverage servings, and number of cannabis concentrate hits used at level 1 (in models limited to days on which cannabis use occurred).

To explore reverse directionality in the relationships between simultaneous use and sleep, we specified two multinomial logistic regression models examining how night-level sleep indices (as independent variables) related to likelihood of engaging in simultaneous use relative to single substance or no use (dependent variable). In the first of these models, simultaneous use was specified as the reference category; in the second, no-use was specified as the reference category to examine differences between single-substance use and no-use days. All sleep indices (i.e., subjective sleep quality, sleep duration, and bedtime) were included as simultaneous predictors in each model. For these models, substance use variables were lagged by a day so that previous night sleep data reported on a given daily morning survey was specified as a predictor of substance use later in that day, as reported in the next-day daily morning survey. For this

reason, participants could contribute up to 20 days to this analysis, and days that were missing a morning survey on either the current or previous day were treated as missing.

All multilevel models specified a level 1 (i.e., day-level) covariate of weekend (Friday–Sunday, coded as 1) versus weekday (Monday–Thursday, coded as 0). Level 2 (i.e., person-level) covariates of age and sex assigned at birth were also included in all models. All level 1 variables were person-mean centered, and person-level means of all level 1 variables were entered on level 2 to disaggregate within- and between-person variance in these variables (Enders & Tofighi, 2007). All level 2 variables were grand-mean centered. Random intercepts were estimated in all models. We examined how the addition of a random slope for each level 1 association impacted model fit (examined one at a time), and retained random slopes that lowered the Bayes Information Criterion (BIC) relative to the fixed slope model. Random slopes were not included in the models in which type of use day was specified as the outcome because they are challenging to estimate with a multicategorical outcome.

The Maximum Likelihood (ML) estimator was used for all models, which retains participants with partially missing data (i.e., missing data on some days) in the analyses. Within our main sleep outcome models, we retained all $N = 150$ participants. Secondary sleep models controlling for cannabis retained $n = 131$ participants (excluding those who did not report cannabis use over the course of the EMA period), while those controlling for alcohol retained $n = 126$ participants (excluding those who did not report alcohol use over the course of the EMA period). Main substance use type outcome models included $n = 148$ after excluding two participants who did not provide at least two consecutive daily surveys.

Transparency and Openness

We report how we determined our sample size, all data exclusions, and all data

manipulations. For brevity, only measures relevant to the current analyses are described here (see Wardell et al., 2024, for additional study details). Hypotheses and analyses were preregistered on OSF on July 5, 2024 (Moore, 2025) and analyses began on July 20, 2024. De-identified data and analysis code are available (subject to IRB approval) by emailing the last author.

Results

Descriptive Statistics

The average completion rate of daily morning surveys was 89.08%. Across all completed daily morning surveys within the 21-day EMA period, participants reported 429 (15.29%) simultaneous use days, 712 (25.37%) cannabis-only use days, 241 (8.59%) alcohol-only use days, and 1424 (50.75%) no-use days. 104 participants (69.33%) reported at least one simultaneous use day, 111 (74.00%) reported at least one cannabis-only use day, 79 (52.67%) reported at least one alcohol-only use day, and 136 (90.67%) reported at least one no-use day. Across all substance use days, within-person correlations between sleep outcomes ranged from -0.57 to 0.26, and between-person correlations ranged from -0.42 to 0.13. Tables 1 and 2 present additional descriptive data on variables assessed at the person- and day-levels, respectively.

Multilevel Models with Sleep Indices as Outcome Variables

Subjective Sleep Quality. In the main model with simultaneous use as the reference category, there were no significant interactions between problematic use (operationalized as participants' AUDIT and CUDIT-R scores at baseline) and day type (all $p > .05$), so the model was trimmed of all interaction terms and rerun. The results of the trimmed model are shown in Table 3. Results revealed that participants tended to report significantly worse sleep quality on days during which they did not engage in alcohol or cannabis use, as well as on days during which they engaged in alcohol-only use, compared to days during which they used both alcohol

and cannabis. There was no significant difference in subjective sleep quality on cannabis-only use days relative to simultaneous use days. Additionally, there were no significant main effects of AUDIT or CUDIT-R scores on subjective sleep quality (see Table 3).

Given the significant difference in subjective sleep quality on alcohol-only use days relative to simultaneous use days, we ran a post-hoc model controlling for number of standard drinks when examining the difference between alcohol-only and simultaneous use days, with alcohol-only days as a reference category. There were no significant interactions between problematic use and day type (all $p > .05$), so the model was trimmed of all interaction terms and rerun. The full results of the final trimmed model are shown in Supplementary Table A. This model confirmed that the better sleep quality reported on simultaneous use days relative to alcohol-only days still held when controlling for alcohol quantity.

We next ran a post-hoc model with no-use days as the reference category to observe whether alcohol- and cannabis-only days differed from no-use days in their associations with subjective sleep quality. In this model, there were no significant interactions between problematic use and day type (all $p > .05$), so all interaction terms were trimmed. Results revealed that participants tended to report better sleep quality on days during which they engaged in cannabis-only use compared to days during which they used neither alcohol nor cannabis (see Supplementary Table B). Conversely, participants tended to report worse sleep quality on days they consumed only alcohol relative to days they used neither alcohol nor cannabis.

Sleep Duration. In the main model with simultaneous use as the reference category, there was a significant interaction between AUDIT and two of the dummy coded day type variables (alcohol-only vs. simultaneous use days and cannabis-only vs. simultaneous use days). However, CUDIT-R did not show any significant interactions with day type, so the model was

trimmed of these interaction terms and rerun. The results of the trimmed model are shown in Table 3. Probing the interactions revealed that individuals with high AUDIT scores (i.e.,1SD above the mean = 12.64) slept less on both alcohol-only use days, b = -0.67, SE = 0.17, p = <.001, and cannabis only use days, b = -0.31, SE = 0.13, p = .020, relative to simultaneous use days. However, there were no significant differences in sleep duration between alcohol only days, b = 0.04, SE = 0.20, p = .835, or cannabis only days, b = 0.16, SE = 0.15, p = .288, and simultaneous use days for those with low AUDIT scores (i.e., 1SD below the mean = 3.54; see Figure 1). There were no significant main effects of AUDIT or CUDIT-R.

Given the significant difference in sleep duration on alcohol-only and cannabis only use days relative to simultaneous use days, we ran post-hoc models controlling for number of standard drinks (in a model comparing alcohol-only days to simultaneous use days) and controlling for quantities of various forms of cannabis used (in a model comparing cannabis-only days to simultaneous use days). In the alcohol days model, the interaction between day type and AUDIT was no longer significant (all p > .05) and no other significant interactions were observed, so the model was trimmed of all interaction terms and rerun. The final trimmed model (shown in Supplementary Table A) revealed that simultaneous use days were associated with longer sleep duration relative to alcohol-only days when controlling for alcohol quantity. Number of standard drinks was also negatively associated with sleep duration. In the cannabis days model, the interaction between alcohol problem severity and day type was still significant (for simultaneous vs. cannabis-only days) but no interactions with CUDIT-R were observed, so the model was trimmed of the CUDIT-R interaction term and rerun. The full results of the final trimmed model are shown in Supplementary Table C. This model confirmed that there was a significant conditional association of simultaneous use days (vs. cannabis-only use days) with

longer sleep duration at high levels of the AUDIT, $b = 0.46$, $SE = 0.16$, $p = .004$, but not low levels of the AUDIT, $b = -0.18$, $SE = 0.17$, $p = .298$, even when controlling for quantities of cannabis used (see Supplementary Figure A).

In the post-hoc sleep duration model with no-use as the reference category, there were no significant interactions between problematic use and day type (all $p > .05$), so the model was trimmed of all interaction terms and rerun (See Supplementary Table B). Results revealed that alcohol-only use was associated with shorter sleep duration relative to no-use. There was no significant difference in sleep duration on cannabis-only use days relative to no-use days.

Bedtime. In the main model with simultaneous use as the reference category, there was a significant interaction between AUDIT and two of the dummy coded day type variables (no-use vs. simultaneous use days and alcohol-only vs. simultaneous use days). However, CUDIT-R did not show any significant interactions with day type, so the model was trimmed of these interactions and rerun. The results of the trimmed model revealed that participants tended to go to bed earlier on no-use days and cannabis-only use days compared to simultaneous use days, with no significant difference in bedtime between alcohol-only and simultaneous use days (see Table 3). However, associations between earlier bedtime and both no-use and alcohol-only (vs. simultaneous use) days were qualified by significant cross-level interactions with AUDIT scores (see Table 3). Probing the interactions revealed that individuals with low AUDIT scores went to bed earlier on no-use days, $b = -0.53$, $SE = 0.12$, $p = <.001$, and alcohol-only days, $b = -0.32$, $SE = 0.16$, $p = .043$, than on simultaneous use days; however, those with high AUDIT scores went to bed later on alcohol-only versus simultaneous use days, $b = 0.27$, $SE = 0.14$, $p = .047$, and showed no differences in bedtime on no-use versus simultaneous use days for, $b = -0.20$, $SE = 0.10$, $p = .054$ (see Figure 2). There were no main effects of AUDIT or CUDIT-R on bedtime.

We ran two post-hoc models to explore these results further. Given the significant difference in bedtime on cannabis-only use days relative to simultaneous use days, we first ran a post-hoc model controlling for quantity and form of cannabis used with cannabis-only days as the reference category. The full results of the final trimmed model are shown in Supplementary Table C. This model confirmed that individuals go to bed later on days where they engage in simultaneous alcohol and cannabis use relative to cannabis-only use, over and above the effects of amount of cannabis consumed. Interestingly, in this model this difference was qualified by a significant cross-level interaction with AUDIT, such that this differences was only significant for those with lower AUDIT scores, $b = 0.50$, $SE = 0.13$, $p = <.001$, but not for those with higher AUDIT scores, $b = 0.16$, $SE = 0.12$, $p = .196$ (see Supplementary Figure B, panel A).

A second post-hoc model was specified controlling for number of standard drinks on alcohol-only and simultaneous use days with alcohol-only days as a reference category. The interaction between AUDIT and day type was still significant, but no interaction with CUDIT-R emerged, so this interaction was trimmed (Supplementary Table A). Probing the interaction with AUDIT revealed that the conditional association of simultaneous use day (versus alcohol-only use day) with earlier bedtime was still signficiant for those with higher scores on the AUDIT, $b = -0.63$, $SE = 0.17$, $p = <.001$, but not those with lower AUDIT scores, $b = 0.28$, $SE = 0.17$, $p = .106$ (see Supplementary Figure B, panel B). This suggests that later bedtimes on alcohol-only versus simulanteous use days among those with low AUDIT scores observed in the main model may be explained by differences in the number of drinks consumed across these day types.

Supplementary Table B shows the final trimmed post-hoc bedtime model with no-use as the reference category. Focusing on the comparisons between alcohol-only and cannabis-only days versus no-use days (neither of which interacted significantly with AUDIT or CUDIT-R),

results revealed that participants tended to go to bed later on days during which they engaged in alcohol-only use compared to days during which they used neither alcohol nor cannabis. There was no significant difference in bedtime on cannabis-only use days relative to no-use days.

Multilevel Models with Substance Use Day Type as Outcome Variables

The results of the model examining the reverse associations, with sleep indices predicting use day type are shown in Table 4. Previous-night sleep quality, sleep duration, and bedtime reported in the morning did not predict likelihood of engaging in no-use, cannabis-only use, or alcohol-only use versus simultaneous use later that day. The results of the post-hoc model with no-use as the reference category (Supplementary Table D) showed no signification associations between the sleep predictors (i.e., subjective sleep quality, sleep duration, and bedtime) and the likelihood of engaging in alcohol-only, cannabis-only, or simultaneous use relative to no use.

Discussion

Given the high prevalence of simultaneous alcohol-cannabis use among young adults, there is a need to clarify the mixed findings in existing research on the associations between simultaneous use and sleep. The present study examined daily-level relationships between single and simultaneous alcohol and cannabis use and key sleep indices (i.e., subjective sleep quality, sleep duration, and bedtime) among young adults who use alcohol and cannabis regularly. We found that participants reported significantly better sleep quality on days when they engaged in cannabis-only use, and worse sleep quality, shorter sleep duration, and later bedtime on days that they reported alcohol-only use, relative to days they used neither substance. These results align with general findings in the literature suggesting that cannabis may have acute sleep enhancing effects (e.g., Babson & Bonn-Miller, 2014; Campbell et al., 2020; Goodhines et al., 2019; Tervo-Clemmens et al., 2023) whereas alcohol may have detrimental effects on sleep (e.g., Fucito et al.,

2018; Goodhines et al., 2019; Lydon et al., 2016; Muzumdar et al., 2023; Van Reen et al., 2016). This study also contributes to the small literature on the specific daily-level associations of simultaneous cannabis and alcohol use with sleep. Results revealed that alcohol-only use days were associated with worse sleep outcomes (i.e., poorer sleep quality, shorter sleep duration) than simultaneous use days, whereas cannabis-only use was associated with earlier bedtimes than simultaneous use. Importantly, this study meaningfully extends upon previous EMA studies by examining the moderating roles of problematic alcohol and cannabis use, finding some of these associations were moderated by severity of alcohol problems. Further, this study was one of the first to examine reverse associations between sleep indices and next-day single-substance simultaneous alcohol and cannabis use, observing no evidence for these reverse associations.

Given prior research broadly suggesting sleep-promoting properties of cannabis (Babson & Bonn-Miller, 2014; Tervo-Clemmens et al., 2023) and sleep-impairing effects of alcohol (Lydon et al., 2016; Van Reen et al., 2016), it was hypothesized that participants would experience better sleep on cannabis-only use days relative to simultaneous use days. This hypothesis received mixed support; no differences in subjective sleep quality and sleep durations were observed, although participants went to bed approximately 20 minutes earlier on cannabis-only days compared to simultaneous use days. This pattern held even when controlling for cannabis quantity, which also predicted earlier bedtimes. Although the differences in bedtime are modest, these effects reflect a reliable pattern of going to bed later on simultaneous use vs. cannabis-only days. While our study did not directly assess long-term health effects, prior research shows that regularity in sleep timing (i.e., consistent bed and wake times) is important for health and may predict health risks beyond sleep duration alone (e.g., Windred et al., 2024).

The lack of evidence for better sleep quality on nights following cannabis-only use

compared to simultaneous use is inconsistent with EMA studies to date, which have found that subjective sleep quality was better on cannabis-only days relative to simultaneous use days (Graupensperger et al, 2021; Sznitman et al., 2023a, 2023b). These discrepant findings may be attributable to methodological differences across studies, such as variations in cannabis quantities and forms used, which were not consistently reported in prior studies. Our differing results may also stem from our analytic approach of controlling for severity of alcohol and cannabis use problems, which only one of these prior studies addressed (Sznitman et al., 2023b). Although we can only speculate on factors explaining the discrepant findings, our study suggests that cannabis-only use is not always associated with better sleep than simultaneous alcohol and cannabis use. Indeed, among young adults with greater alcohol problem severity, we found that cannabis-only use was associated with *shorter* sleep duration than simultaneous use, underscoring the importance of considering individual use patterns.

Consistent with literature linking alcohol use with poor sleep outcomes (Goodhines et al., 2019a; Fucito et al., 2018; Lydon et al., 2016; Muzumdar et al., 2023), it was hypothesized that participants would experience worse sleep on alcohol-only use days relative to simultaneous use and no-use days. This hypothesis was supported. Echoing prior research (Graupensperger et al., 2021; Sznitman et al., 2023a; Wycoff et al. 2024), participants reported significantly worse subjective sleep quality on alcohol-only use days compared to days of simultaneous use or no use, and this relationship held even when controlling for the quantity of alcohol consumed. Additionally, alcohol-only use was associated with shorter sleep duration compared to simultaneous use and no-use days. These findings suggest that while alcohol use generally impairs subjective sleep quality and duration, such effects are attenuated when cannabis is used simultaneously, at least among those who use cannabis regularly. Finally, while there was no

significant difference in bedtime on alcohol-only use days compared to simultaneous use days, participants went to bed 20 minutes later on average on alcohol-only days relative to no-use days, a difference that was statistically significant. The lack of difference in bedtime between alcohol-only and simultaneous days may be due to the context of alcohol use; young adults tend to engage in both alcohol-only and simultaneous use in social settings that involve staying up late, such as parties and bars (Farrelly et al., 2025; Gunn et al., 2021; Jackson et al., 2021).

Contrary to hypotheses, there were no significant main effects of severity of alcohol and/or cannabis use problems on subjective sleep quality, sleep duration, or bedtime. However, the study did observe significant interactions involving alcohol use severity (as measured by the AUDIT). In our main models, participants with lower alcohol problem severity reported earlier bedtimes on no-use and alcohol-only use days relative to simultaneous use days by 32 and 19 minutes, respectively, although the latter difference appeared to be driven by differences in quanitites of alcohol consumed across day types. Further, after controlling for quantity of cannabis flower consumed, results revealed participants with lower alcohol problem severity also went to bed approximately 30 minutes earlier on cannabis-only than simultaneous use days. For individuals with low alcohol problem severity, later bedtime during simultaneous use may reflect social patterns of use, where alcohol is primarily consumed alongside cannabis during social gatherings that extend later into the night (Farrelly et al., 2025; Gunn et al., 2021; Jackson et al., 2021). However, this explanation is speculative, and future research should assess the role of contextual factors in the effects of simultaneous use on sleep.

Conversely, participants with higher alcohol problem severity slept less on alcohol-only and cannabis-only days relative to simultaneous use days, and they went to bed an average of 16 minutes later on alcohol-only compared to simultaneous use days. Inspection of Figure 1

suggests that individuals with greater alcohol problem severity slept the fewest hours on alcohol use days overall, especially when using only alcohol and not cannabis. For them, combining cannabis with alcohol may potentially offset this negative effect of alcohol on sleep, which appears to be driven by differences in amount of alcohol consumed across alcohol-only and simultaneous use days. This aligns with the existing literature, which demonstrates that heavy alcohol use and alcohol dependence are particularly detrimental to sleep compared to occasional or non-problematic use (Angarita et al., 2016; Chakravorty et al., 2016). Our findings may reflect an attempt by individuals with problematic alcohol use patterns to manage the sleep-disrupting effects of heavy alcohol use through use of cannabis as a sleep aid, although future research assessing simultaneous use motives is necessary to confirm this speculation.

Finally, models examining the impacts of sleep variables on next-day substance use did not reveal any unique main effects. Specifically, previous-night subjective sleep quality, sleep duration, and bedtime reported in the morning did not predict likelihood of engaging in no-use, cannabis-only use, or alcohol-only use versus simultaneous use later that day, nor did they predict likelihood of engaging in cannabis-only or alcohol-only use relative to no-use. This suggests that poor sleep is not a reliable proximal predictor of next-day substance use. These findings are inconsistent with Wycoff and colleagues' (2024) recent finding that longer sleep duration predicted increased likelihood of next-day cannabis use, as well as the broader literature suggesting that sleep can impact next-day substance use choices (Davis et al., 2025). It is possible that among the young adult sample in this study, substances were used more for entertainment and social connection purposes than for coping reasons (Kuntsche et al., 2005; Lee et al., 2007). Additionally, this was not a sample selected for sleep disturbances, so associations between poor sleep and using substances to cope may be stronger among individuals with

clinically significant sleep impairment. Finally, shorter sleep duration and poorer sleep quality may predominantly influence substance cravings over actual use behaviors (Graupensperger et al., 2022; Wycoff et al., 2024), such that individuals might experience stronger urges to use alcohol and cannabis following poor sleep, but still exercise self-control over their actual consumption decisions (Graupensperger et al., 2022).

Limitations

There were some important limitations to this study. First, all sleep data were self-report, which could be prone to reporting biases. It is important to emphasize that these sleep outcomes reflect participants' subjective reports rather than objective physiological measures. Further, our use of one-hour ranges for bedtime and wake time, and the fact that response options were truncated (e.g., "3am or later" for bedtimes, "3pm or later" for wake time), limited our ability to precisely calculate bedtime and total sleep time for those days. Future research should obtain more precise estimates of bedtime, sleep duration, sleep-onset latency, and nightly awakenings, supplemented with biometric technology to provide objective indicators of sleep quality and quantity (see Smith et al., 2018). Second, we did not directly measure the concentrations of delta-9-tetrahydrocannabinol (THC) and other sleep-relevant cannabinoids, nor did we measure sleep-specific motivation for substance use. Future research would benefit from examining whether simultaneous use as a sleep aid is associated with different sleep outcomes than simultaneous use associated with other motives. We also did not screen for sleep disorders in the sample, which could provide important context for interpreting the findings. Another limitation concerns our operationalization of simultaneous use as same-day co-use of alcohol and cannabis. While this approach accommodates the delayed effects of some forms of use (e.g. cannabis edibles), it is possible that some observations categorized as simultaneous use days were not

actually reflective of co-use with overlapping effects. Furthermore, we did not control for context of use, such as whether substance use occurred in social versus solitary settings. Future research should investigate whether social context, rather than type of use, plays a more central role in influencing sleep indices like bedtime. Additionally, we did not include measures of daytime functioning such as next-day fatigue. Some prior work suggests that while cannabis use may be associated with increased sleep duration, it has also been linked to greater next-day fatigue (e.g., Goodhines et al., 2019). Thus, these findings should be interpreted in the context of sleep outcomes alone. Another limitation relates to the young age of our sample, which may preclude insights into the cumulative effects of heavy and problematic use on sleep over time. Finally, it is important to emphasize that the findings apply specifically to young adults who regularly use cannabis and alcohol; findings may not generalize to young adults who engage in alcohol and cannabis use infrequently, who are attempting to quit or cut down on their use, who use illicit drugs regularly, or who live in jurisdictions where cannabis is not legal.

Conclusions

This study found that simultaneous use of alcohol and cannabis was linked with better subjective sleep quality compared to alcohol-only use, but also with later bedtimes compared to cannabis-only use, and that several associations depended on individual differences in alcohol problem severity. That alcohol problem severity moderated simultaneous use's associations with sleep represent an important contribution to the literature, highlighting the need for future research to evaluate the efficacy and feasibility of tailored sleep interventions based on individual simultaneous use patterns and alcohol problem severity.

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Table 1. Sample characteristics

	n	%
Sex		
Male	54	36.00
Female	96	64.00
Gender		
Man	57	38.00
Woman	90	60.00
Transgender	2	1.33
Nonbinary	4	2.67
Race/ethnicity		
White	94	62.67
Black	13	8.67
Asian	24	16.00
Pacific Islander	2	1.33
Indigenous/Native North American	1	0.67
East Indian	14	9.33
Middle Eastern	6	4.00
Other	6	4.00
Prefer not to respond	2	1.33
Annual household income		
≤ $49.999	80	53.33
$50,000–$99,999	34	22.67
$100,000–$199,999	22	14.67
≥ $200,000	12	8.00
AUDIT met threshold for hazardous use	67	44.67
CUDIT-R met threshold for hazardous use	92	61.33

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Sample characteristics were assessed at baseline using data from all $N = 150$ participants.

Table 2. Person- and day-level descriptive statistics

Person-level variables	*n* NA	*M* (*SD*)	Range
AUDIT score	0	8.07 (4.65)	2–27
CUDIT-R score	0	10.07 (5.37)	2–25
Person-level mean number of no-use days	0	9.49 (6.29)	0–21
Person-level mean number of alcohol-only use days	0	1.61 (2.32)	0–12
Person-level mean number of cannabis-only use days	0	4.75 (5.02)	0–21
Person-level mean number of simultaneous use days	0	2.86 (3.35)	0–21
Person-level mean number of standard drinks consumed across all alcohol use days	3	3.50 (2.19)	0.75–12.75
Person-level mean grams of cannabis flower used across all cannabis use days	4	0.40 (0.53)	0–3.03
Person-level mean number of concentrate hits used across all cannabis use days	1	1.18 (2.44)	0–12
Person-level mean number of edible/beverage servings consumed across all cannabis use days	1	0.28 (0.55)	0–2.85
Day-level variables from daily surveys	*n* NA	*n*	%
Day of week	0		
Weekday		1612	57.45
Weekend day		1194	42.55
Bedtime[a]	2		
Before 9:00PM		43	1.53
9:00 PM to 9:59 PM		79	2.82
10:00 PM to 10:59 PM		314	11.19
11:00 PM to 11:59 PM		533	19.00
12:00 AM to 12:59 AM		659	23.49
1:00 AM to 1:59 AM		496	17.68
2:00 AM to 2:59 AM		349	12.44
3:00 AM or later		331	11.80
Used cannabis flower (yes)	0	822	29.29
Used cannabis concentrates (yes)	0	253	9.02
Used cannabis edibles (yes)	0	186	6.63
	n NA	*M* (*SD*)	Range
Sleep quality	2	3.44 (0.96)	1–5
Sleep duration (hours)	3	8.21 (1.75)	2–15
Number of standard drinks consumed	3	0.85 (2.06)	0–17
Number of grams of cannabis flower used	4	0.21 (0.55)	0–5.3
Number of concentrate hits used	1	0.58 (2.43)	0–31
Number of edible/beverage servings consumed	1	0.11 (0.53)	0–6

Note. n NA = number of missing values. Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) and Cannabis Use Disorder Identification Test–Revised (CUDIT-R; Adamson et al., 2010) were assessed at baseline. Other person-level descriptives were calculated from daily surveys using all $N = 150$ participants and data from all available days, not limiting to those included in models. Day-level descriptives were calculated using data from all available days ($n = 2806$), not limiting to those included in models.

Table 3. Final multilevel models examining sleep outcomes as a function of day type with simultaneous use days as the reference category

	Subjective sleep quality[a]			Sleep Duration[b]			Bedtime[c]		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	**3.43**	**0.04**	**<.001**	**8.21**	**0.07**	**<.001**	**4.26**	**0.10**	**<.001**
Level 1									
No-use (vs. simultaneous use)	**-0.14**	**0.05**	**.010**	0.00	0.10	.974	**-0.37**	**0.08**	**<.001**
Alcohol-only use (vs. simultaneous use)	**-0.28**	**0.07**	**<.001**	**-0.31**	**0.14**	**.023**	-0.03	0.11	.819
Cannabis-only use (vs. simultaneous use)	0.03	0.06	.596	-0.07	0.11	.487	**-0.33**	**0.09**	**<.001**
Weekend vs. weekday	-0.01	0.03	.687	**0.12**	**0.06**	**.044**	**0.21**	**0.05**	**<.001**
Level 2									
Proportion of no-use days vs. simultaneous use days	-0.41	0.28	.145	-0.45	0.46	.336	**1.25**	**0.61**	**.042**
Proportion of alcohol-only use vs. simultaneous use days	-0.14	0.51	.782	0.42	0.85	.624	0.36	1.11	.747
Proportion of cannabis-only use vs. simultaneous use days	0.15	0.34	.649	0.34	0.56	.538	0.96	0.73	.192
Proportion of weekend vs. weekday	1.00	0.92	.286	-0.59	1.57	.706	-3.10	1.89	.103
AUDIT	0.00	0.01	.690	-0.03	0.02	.078	0.00	0.02	.931
CUDIT-R	-0.01	0.01	.245	0.02	0.02	.254	0.03	0.02	.241
Age	0.00	0.02	.944	-0.01	0.04	.709	-0.08	0.05	.107
Sex – female (vs. male)	-0.13	0.09	.157	**0.37**	**0.16**	**.019**	**-0.41**	**0.21**	**.048**
Cross-level interactions									
No-use x AUDIT	–	–	–	-0.02	0.02	.270	0.04	0.02	0.27

Alcohol-only use x AUDIT	–	–	–	**-0.08**	**0.03**	**.003**	**0.06**	**0.02**	**.002**
Cannabis-only use x AUDIT	–	–	–	**-0.05**	**0.02**	**.015**	0.03	0.02	.110
Random effects	Variance		*SD*	Variance		*SD*	Variance		*SD*
Random intercept	0.25		0.50	0.66		0.81	1.29		1.13

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level means of the substance use day type dummy variables and day of week dummy variable were grand-mean centered. Each sleep outcome variable (i.e., subjective sleep quality, sleep duration, and bedtime) was examined in a separate model. After excluding rows that were missing data on one or more model variables, the models included 150 participants and 2804 participant days in the subjective sleep quality and bedtime models, and 150 participants and 2803 participant days in the sleep duration model.

[a] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +18.9) and the weekend versus weekday indicator (ΔBIC = +11.9) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

[b] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +21) and the weekend versus weekday indicator (ΔBIC = +11) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

[c] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +11.6) and the weekend versus weekday indicator (ΔBIC = +4.2) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

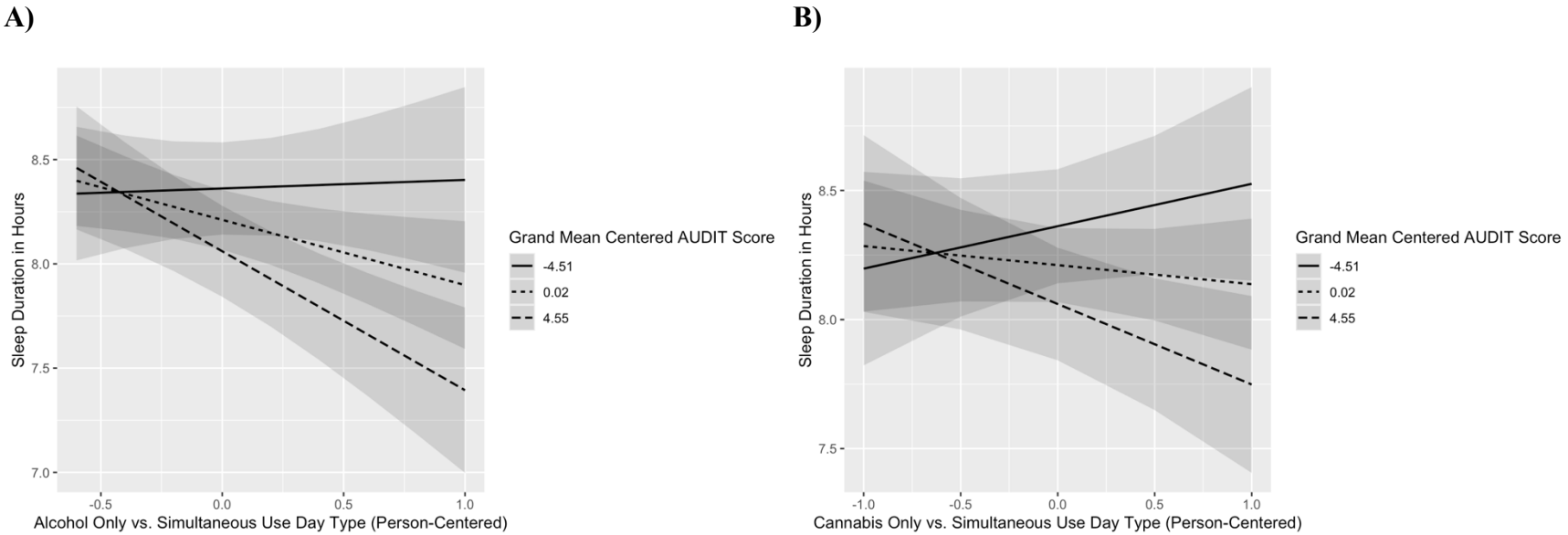
Table 4. Final multilevel model examining day type as a function of sleep indices with simultaneous use days as the reference category

	No-use vs. simultaneous use [ref.]				Alcohol-only use vs. simultaneous use [ref.]				Cannabis-only use vs. simultaneous use [ref.]			
	b	*SE*	*p*	OR[a]	*b*	*SE*	*p*	OR[a]	*b*	*SE*	*p*	OR[a]
Level 1												
Subjective sleep quality	-0.07	0.09	.426	0.93	-0.10	0.12	.392	0.90	-0.03	0.10	.789	0.97
Sleep duration	-0.01	0.06	.850	0.99	-0.04	0.08	.604	0.96	-0.05	0.06	.435	0.95
Bedtime	-0.04	0.07	.591	0.96	-0.02	0.10	.862	0.98	-0.01	0.07	.932	0.99
Weekend vs. weekday	**-1.09**	**0.14**	**<.001**	**0.34**	**-0.61**	**0.19**	**.001**	**0.54**	**-0.99**	**0.15**	**<.001**	**0.37**
Level 2												
Subjective sleep quality	-0.32	0.30	.249	-	-0.33	0.33	.320	-	0.41	0.29	.158	-
Sleep duration	-0.31	0.19	.099	-	-0.05	0.20	.794	-	0.19	0.18	.279	-
Bedtime	0.18	0.15	.244	-	0.05	0.16	.776	-	0.23	0.15	.125	-
Proportion of weekend vs. weekday	-0.64	1.87	.734	-	0.07	2.29	.977	-	2.07	1.82	.257	-
AUDIT	-0.05	0.04	.205	-	0.05	0.04	.196	-	**-0.11**	**0.04**	**.002**	-
CUDIT-R	**-0.19**	**0.03**	**<.001**	-	**-0.19**	**0.04**	**<.001**	-	**0.09**	**0.03**	**.010**	-
Age	-0.03	0.07	.689	-	0.04	0.08	.569	-	-0.02	0.07	.790	-
Sex – female (vs. male)	0.14	0.33	.661	-	0.14	0.35	.694	-	**0.70**	**0.32**	**.031**	-

Note. OR = odds ratio; AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level means of the sleep variables and day of week dummy variable were grand-mean centered. Including random slopes for the sleep predictor variables and the weekend versus weekday indicator resulted in a nonconvergent model. Thus, the final model included only a random intercept with fixed slopes. After excluding rows that were missing data on one or more model variables, the model included 148 participants and 2478 participant days.

[a]ORs are only relevant at Level 1. At level 2, each outcome is a latent between-person variable with a continuous distribution.

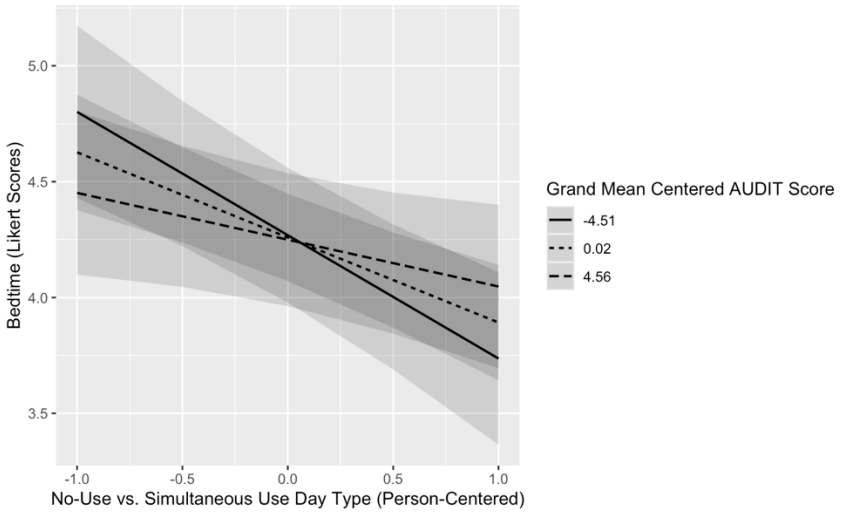
Figure 1. Cross-level interaction between AUDIT scores and alcohol-only (vs. simultaneous) use days (panel A) and cannabis-only (vs. simultaneous) use days (panel B) predicting sleep duration



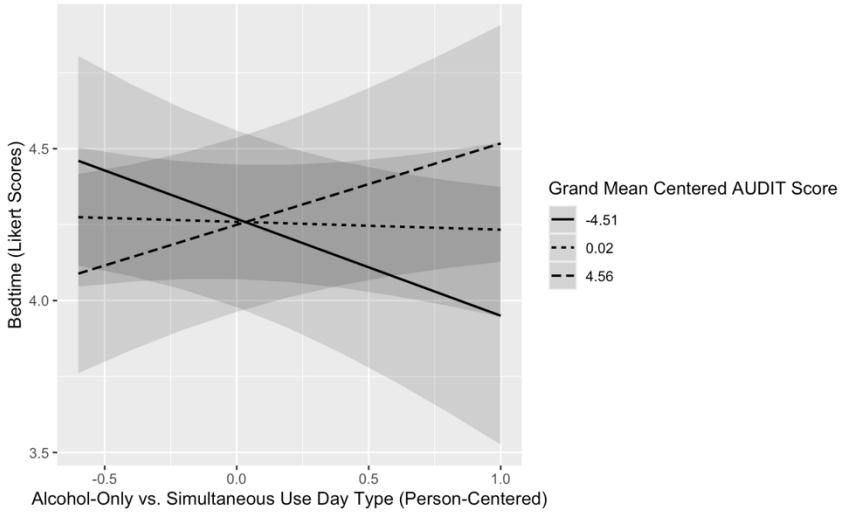
Note. The x-axis shows the person-mean-centered dummy coded day type variables. As the dummy coded variables are person-mean centered, positive values on the x-axis represent alcohol-only use days (in Panel A) and cannabis-only days (in Panel B), whereas negative values represent simultaneous use days in both panels. The y-axis covers 2 standard deviations above and below the sleep duration mean. The solid line represents one standard deviation below the mean Alcohol Use Disorders Identification Test (AUDIT) score, the line with shorter dashes represents the mean AUDIT score (grand-mean centered), and line with longer dashes represents one standard deviation above the mean AUDIT score. Error bars show the 95% confidence interval.

Figure 2. Cross-level interaction between AUDIT scores and no-use (vs. simultaneous) use days (panel A) and alcohol-only (vs. simultaneous) use days (panel B) predicting bedtime

A)



B)



Note. The x-axis shows the person-mean-centered dummy coded day type variables. As the dummy coded variables are person-mean centered, positive values on the x-axis represent no-use days (in Panel A) and alcohol-only days (in Panel B), whereas negative values represent simultaneous use days in both panels. Values on the y-axis represent the 1–7 categorical bedtime scale, with each scale value except the upper and lower bounds of the scale associated with a 1-hour range in bedtime (0 = *before 9pm*, 1 = *9pm–9:59pm*, 2 = *10pm–10:59pm*, 3 = *11pm–11:59pm*, 4 = *12am–12:59am*, 5 = *1am–1:59am*, 6 = *2am–2:59am*, 7 = *3am or later*). The y-axis covers 2 standard deviations above and below the bedtime mean. The solid line represents one standard deviation below the mean Alcohol Use Disorders Identification Test (AUDIT) score, the line with shorter dashes represents the mean AUDIT score (grand mean centered), and the line with longer dashes represents one standard deviation above the mean AUDIT score. Error bars show the 95% confidence interval.

Supplementary Materials

Table A. Final multilevel models examining sleep outcomes as a function of day type and controlling for alcohol quantity with alcohol-only use days as the reference category

	Subjective sleep quality[a]			Sleep Duration[b]			Bedtime[c]		
	b	SE	p	b	SE	p	b	SE	p
Intercept	**3.40**	**0.06**	**<.001**	**8.12**	**0.11**	**<.001**	**4.48**	**0.13**	**<.001**
Level 1									
Simultaneous use vs. alcohol-only use [ref.]	**0.39**	**0.13**	**.003**	**0.53**	**0.17**	**.002**	-0.17	0.12	.160
Standard drinks	-0.01	0.01	.623	**-0.10**	**0.03**	**<.001**	**0.17**	**0.02**	**<.001**
Weekend vs. weekday	-0.11	0.07	.134	0.16	0.13	.225	0.08	0.10	.416
Level 2									
Proportion of simultaneous use days vs. alcohol-only use days	**0.40**	**0.18**	**.030**	0.55	0.36	.125	-0.58	0.38	.136
Standard drinks	-0.05	0.03	.126	**-0.17**	**0.06**	**.007**	0.08	0.07	.247
Proportion of weekend vs. weekday	0.40	0.22	.069	0.78	0.43	.071	0.09	0.45	.834
AUDIT	0.01	0.01	.366	0.00	0.03	.993	-0.04	0.03	.206
CUDIT-R	-0.00	0.01	.783	0.03	0.03	.337	0.04	0.03	.182
Age	-0.00	0.03	.862	-0.05	0.06	.355	-0.12	0.06	.059
Sex – female (vs. male)	-0.16	0.12	.183	0.36	0.24	.146	-0.35	0.27	.198
Cross-level interactions									
Simultaneous use x AUDIT	–	–	–	–	–	–	**-0.09**	**0.02**	**<.001**
Random effects	Variance	SD		Variance	SD		Variance	SD	
Random intercept	0.25	0.50		0.98	0.99		1.55	1.24	
Random slope for the simultaneous use type dummy variable	0.40	0.63		–	–		–	–	

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level

means of standard drinks, the simultaneous use day type dummy variable, and day of week dummy variable were grand-mean centered. Each sleep outcome variable (i.e., subjective sleep quality, sleep duration, and bedtime) was examined in a separate model. After excluding rows that were missing data on one or more model variables, the model included 126 participants and 670 participant days in the subjective sleep quality model, and 126 participants and 669 participant days in the sleep duration and bedtime models.

[a] Including a random slope for standard drinks (ΔBIC = + 12.3) did not improve model fit, and including a random slope for the weekend versus weekday indicator resulted in a nonconvergent model. Model fit was improved with the addition of a random slope for simultaneous use day type (ΔBIC = –0.2). Thus, the final model included only a random intercept with fixed slopes and a random slope for simultaneous use day type.

[b] Including the random slopes for simultaneous use day type (ΔBIC = +7.5), standard drinks (ΔBIC = + 11.3), and the weekend versus weekday indicator (ΔBIC = + 9.3) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

[c] Including the random slopes for simultaneous use day type (ΔBIC = +11) and standard drinks (ΔBIC = +10.5) did not improve model fit, and adding a random slope for the weekend versus weekday indicator resulted in a nonconvergent model. Thus, the final model included only a random intercept with fixed slopes.

Table B. Final multilevel models examining sleep outcomes as a function of day type with no-use days as the reference category

	Subjective sleep quality[a]			Sleep Duration[b]			Bedtime[c]		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	**3.43**	**0.04**	**<.001**	**8.21**	**0.07**	**<.001**	**4.26**	**0.10**	**<.001**
Level 1									
Simultaneous use vs. no-use [ref.]	**0.14**	**0.05**	**.010**	0.05	0.10	.631	**0.37**	**0.08**	**<.001**
Alcohol-only use vs. no-use [ref.]	**-0.14**	**0.06**	**.026**	**-0.34**	**0.12**	**.004**	**0.34**	**0.09**	**<.001**
Cannabis-only use vs. no-use [ref.]	**0.17**	**0.05**	**<.001**	-0.07	0.09	.462	0.04	0.07	.578
Weekend vs. weekday	-0.01	0.03	.687	**0.13**	**0.06**	**.035**	**0.21**	**0.05**	**<.001**
Level 2									
Proportion of simultaneous use days vs. no-use days	0.41	0.28	.145	0.45	0.46	.335	**-1.25**	**0.61**	**.042**
Proportion of alcohol-only use vs. no-use days	0.27	0.42	.526	0.86	0.70	.218	-0.89	0.92	.337
Proportion of cannabis-only use vs. no-use days	**0.56**	**0.20**	**.005**	**0.79**	**0.33**	**.018**	-0.29	0.43	.507
Proportion of weekend vs. weekday	0.99	0.92	.287	-0.59	1.57	.706	-3.10	1.89	.103
AUDIT	0.00	0.01	.689	-0.03	0.02	.078	-0.00	0.02	.931
CUDIT-R	-0.01	0.01	.245	0.02	0.02	.254	0.03	0.02	.241
Age	0.00	0.02	.944	-0.01	0.04	.709	-0.08	0.05	.107
Sex – female (vs. male)	-0.13	0.09	.157	**0.37**	**0.16**	**.019**	**-0.41**	**0.21**	**.048**
Cross-level interactions									
Simultaneous use x AUDIT	–	–	–	–	–	–	**-0.04**	**0.02**	**.027**
Alcohol-only use x AUDIT	–	–	–	–	–	–	0.03	0.02	.159
Cannabis-only use x AUDIT	–	–	–	–	–	–	-0.01	0.02	.580

Random effects	Variance	*SD*	Variance	*SD*	Variance	*SD*
Random intercept	0.25	0.50	0.66	0.81	1.29	1.13

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level means of the substance use day type dummy variables and day of week dummy variable were grand-mean centered. Each sleep outcome variable (i.e., subjective sleep quality, sleep duration, and bedtime) was examined in a separate model. After excluding rows that were missing data on one or more model variables, the model included 126 participants and 670 participant days in the subjective sleep quality model, and 126 participants and 669 participant days in the sleep duration and bedtime models.

[a] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +5.9) and the weekend versus weekday indicator (ΔBIC = +11.9) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

[b] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +7) and the weekend versus weekday indicator (ΔBIC = +11) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

[c] Including the random slopes for the set of dummy-coded day type variables (ΔBIC = +3.2) and the weekend versus weekday indicator (ΔBIC = +4.2) did not improve model fit. Thus, the final model included only a random intercept with fixed slopes.

Table C. Final multilevel models examining sleep outcomes as a function of day type and controlling for cannabis form and quantity with cannabis-only use days as the reference category

	Subjective sleep quality			Sleep Duration			Bedtime		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Intercept	**3.55**	**0.05**	**<.001**	**8.34**	**1.02**	**<.001**	**4.24**	**0.12**	**<.001**
Level 1									
Simultaneous use vs. cannabis-only use [ref.]	-0.01	0.06	.808	0.14	0.12	.230	**0.33**	**0.09**	**<.001**
Cannabis flower in grams	0.06	0.06	.267	-0.17	0.12	.141	**0.24**	**0.09**	**.007**
Cannabis concentrate hits	0.01	0.01	.224	0.01	0.02	.722	0.01	0.01	.604
Edible and cannabis beverage servings	0.02	0.04	.559	-0.06	0.08	.470	0.11	0.06	.072
Weekend vs. weekday	-0.06	0.05	.205	0.16	0.10	.105	0.10	0.08	.200
Level 2									
Proportion of simultaneous use days vs. cannabis-only use days	-0.12	0.18	.522	0.02	0.34	.961	-0.42	0.38	.266
Cannabis flower in grams	0.12	0.11	.288	-0.29	0.20	.159	-0.45	0.23	.055
Cannabis concentrate hits	**0.05**	**0.22**	**.038**	-0.01	0.04	.861	-0.07	0.05	.156
Edible and cannabis beverage servings	-0.04	0.10	.668	-0.19	0.19	.307	0.31	0.21	.141
Proportion of weekend vs. weekday	-0.03	0.25	.899	-0.00	0.47	.999	-0.06	0.49	.906
AUDIT	-0.00	0.01	.943	-0.03	0.03	.317	0.00	0.03	.930
CUDIT-R	-0.01	0.01	.581	0.04	0.02	.051	0.02	0.03	.399
Age	0.00	0.03	.989	-0.01	0.05	.913	**-0.13**	**0.05**	**.022**
Sex – female (vs. male)	-0.08	0.12	.487	**0.62**	**0.21**	**.005**	**-0.92**	**0.24**	**<.001**
Cross-level interactions									

Simultaneous use x AUDIT	–	–	–	**0.07**	**0.02**	**.005**	**-0.04**	**0.02**	**.047**
Random effects	Variance	*SD*		Variance	*SD*		Variance	*SD*	
Random intercept	0.26	0.51		0.87	0.93		1.37	1.17	

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level means of grams of cannabis flower, cannabis concentrate hits, edible and beverage servings, the simultaneous use day type dummy variable, and day of week dummy variable were grand-mean centered. Each sleep outcome variable (i.e., subjective sleep quality, sleep duration, and bedtime) was examined in a separate model. After excluding rows that were missing data on one or more model variables, the models included 131 participants and 1140 participant days in the subjective sleep quality and bedtime models, and 131 participants and 1139 participant days in the sleep duration and bedtime models.

[a] Including the random slopes for simultaneous use day type (ΔBIC = +7.2), grams of cannabis flower (ΔBIC = +5), edible and beverage servings (ΔBIC = +11), and the weekend versus weekday indicator (ΔBIC = +10.8) did not improve model fit, and including a random slope for concentrate hits resulted in a nonconvergent model. Thus, the final model included only a random intercept with fixed slopes.

[b] Including the random slopes for simultaneous use day type (ΔBIC = +3.7), concentrate hits (ΔBIC = +13.8), and the weekend versus weekday indicator (ΔBIC = +7.7) did not improve model fit, and including random slopes for grams of cannabis flower and edible and beverage servings resulted in nonconvergent models. Thus, the final model included only a random intercept with fixed slopes.

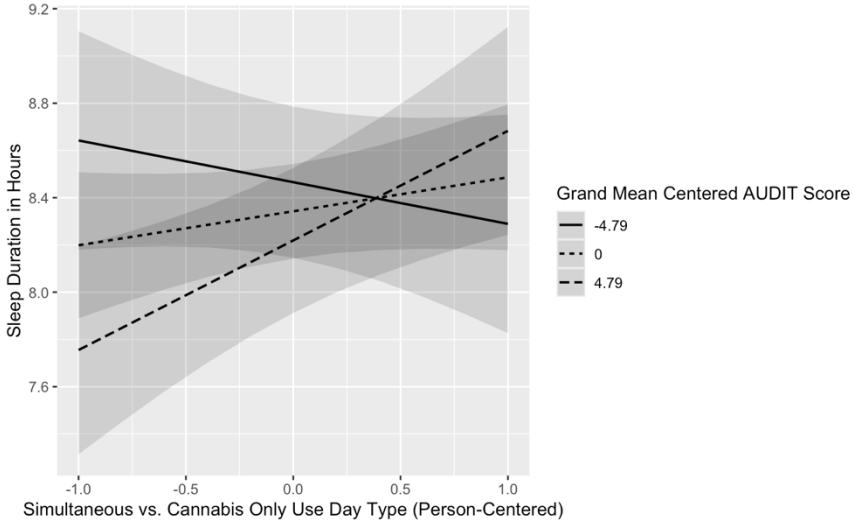
[c] Including the random slopes for simultaneous use day type (ΔBIC = +8.5) and the weekend versus weekday indicator (ΔBIC = +13.8) did not improve model fit, and including random slopes for grams of cannabis flower, concentrate hits, and edible and beverage servings resulted in nonconvergent models. Thus, the final model included only a random intercept with fixed slopes.

Table D. Final multilevel models examining day type as a function of sleep indices with no-use days as the reference category

	Simultaneous use vs. no-use [ref.]			Alcohol-only use vs. no-use [ref.]			Cannabis-only use vs. no-use [ref.]		
	b	*SE*	*p*	*b*	*SE*	*p*	*b*	*SE*	*p*
Level 1									
Subjective sleep quality	0.08	0.09	.390	-0.03	0.10	.742	0.04	0.08	.588
Sleep duration	0.02	0.06	.805	-0.03	0.07	.687	-0.04	0.05	.502
Bedtime	0.04	0.07	.615	0.02	0.07	.843	0.03	0.07	.657
Weekend vs. weekday	**1.12**	**0.15**	**<.001**	**0.41**	**0.16**	**.011**	0.06	0.13	.663
Level 2									
Subjective sleep quality	0.41	0.33	.214	-0.04	0.29	.882	**0.71**	**0.33**	**.031**
Sleep duration	0.27	0.20	.188	0.12	0.19	.508	**0.49**	**0.21**	**.020**
Bedtime	-0.16	0.17	.328	-0.13	0.14	.366	0.11	0.17	.543
Proportion of weekend vs. weekday	-0.44	2.08	.834	-0.39	2.15	.858	2.78	1.99	.162
AUDIT	0.06	0.04	.138	**0.09**	**0.03**	**.013**	-0.08	0.04	.062
CUDIT-R	**0.18**	**0.04**	**<.001**	-0.03	0.03	.418	**0.26**	**0.04**	**<.001**
Age	0.03	0.08	.696	0.09	0.07	.190	0.01	0.08	.915
Sex – female (vs. male)	-0.18	0.35	.620	-0.07	0.31	.817	0.66	0.38	.082

Note. AUDIT = Alcohol Use Disorders Identification Test (Saunders et al., 1993); CUDIT-R = Cannabis Use Disorder Identification Test–Revised (Adamson et al., 2010). Statistically significant effects (at an alpha level of .05) are bolded. All level 1 independent variables were person-mean centered; at level 2, age, sex, AUDIT and CUDIT-R scores, and the person-level means of the sleep variables and day of week dummy variable were grand-mean centered. Including random slopes for the sleep outcome variables and the weekend versus weekday indicator resulted in a nonconvergent model. Thus, the final model included only a random intercept with fixed slopes. After excluding rows that were missing data on one or more model variables, the model included 148 participants and 2478 participant days.

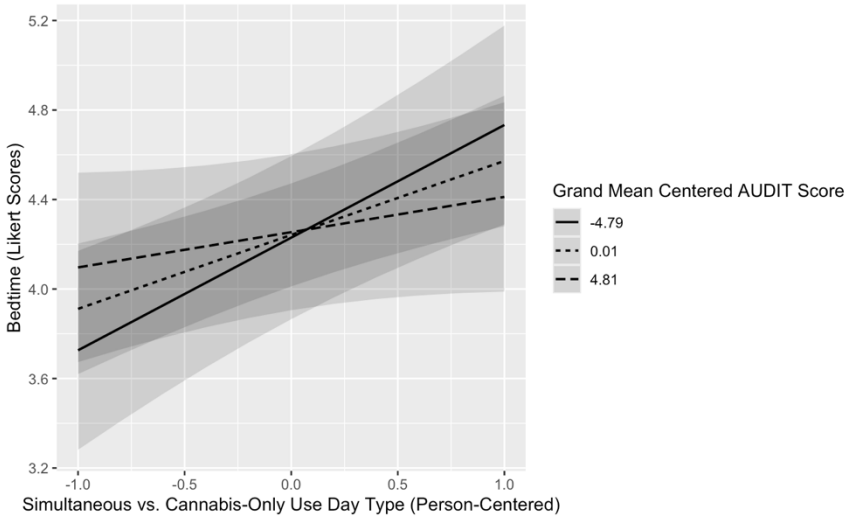
Figure A. Cross-level interaction between AUDIT scores and simultaneous (vs. cannabis-only) use days on sleep duration in post-hoc model controlling for cannabis quantity and form



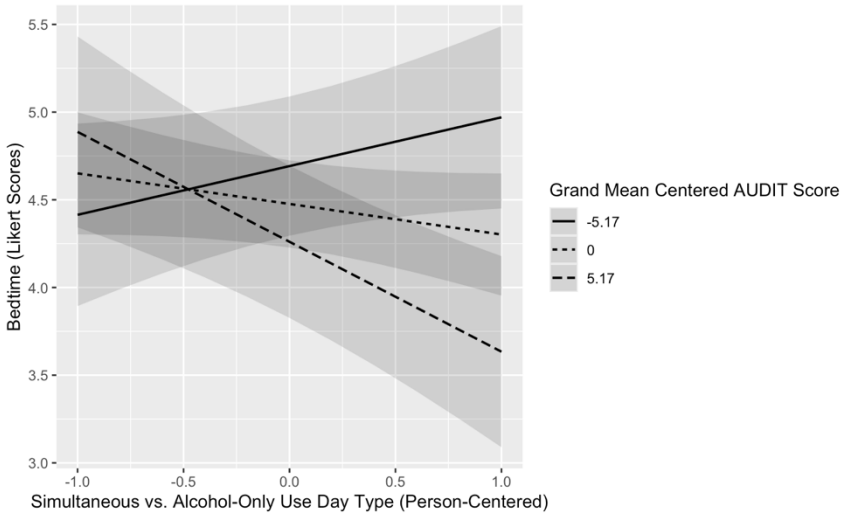
Note. The x-axis shows the person-mean-centered dummy coded day type variables. Positive values on the x-axis represent simultaneous use days and negative values represent cannabis-only use days The y-axis covers 2 standard deviations above and below the sleep duration mean. The solid line represents one standard deviation below the mean Alcohol Use Disorders Identification Test (AUDIT) score, the line with shorter dashes represents the mean AUDIT score, and the line with longer dashses represents one standard deviation above the mean AUDIT score. Error bars show the 95% confidence interval.

Figure B. Cross-level interaction between AUDIT scores and simultaneous (vs. cannabis-only) use days (panel A) and simultaneous (vs. alcohol-only) use days (panel B) on bedtime in post-hoc model controlling for cannabis quantity and form (panel A) and alcohol quantity (panel B)

A)



B)



Note. The x-axis shows the person-mean-centered dummy coded day type variables. In panel A, positive values on the x-axis represent simultaneous use days and negative values represent cannabis-only use days. In panel B, positive values on the x-axis represent simultaneous use days and negative values represent alcohol-only use days. Values on the y-axis represent the 1–7 categorical bedtime scale, with each scale value except the upper and lower bounds of the scale associated with a 1-hour range in bedtime (0 = *before 9pm*, 1 = *9pm–9:59pm*, 2 = *10pm–10:59pm*, 3 = *11pm–11:59pm*, 4 = *12am–12:59am*, 5 = *1am–1:59am*, 6 = *2am–2:59am*, 7 = *3am or later*). The y-axis covers 2 standard deviations above and below the bedtime mean. The solid line represents one standard deviation below the mean Alcohol Use Disorders Identification Test (AUDIT) score, the line with shorter dashes represents the mean AUDIT score, and the line with longer dashes represents one standard deviation above the mean AUDIT score. Error bars show the 95% confidence interval.