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# Nuanced Relations Between Simultaneous Alcohol and Cannabis Use Motives and Negative Consequences Among College Students: The Role of Multiple Product Use

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Simultaneous alcohol and marijuana (SAM) use is common, but it exacerbates negative consequences. Individuals use alcohol and cannabis products in different ways and have distinct reasons for use. The present study examines day-level effects of motives on consequences on SAM-use days, accounting for consumption, and tests whether using multiple alcohol (e.g., beer + liquor) and/or cannabis (e.g., concentrate + leaf) products on the same day mediates these relations. College students engaging in SAM use at least once in the past month ( $N = 281$ ;  $M_{\text{age}} = 20.17$ ) completed two bursts of 28 consecutive days of data collection. We examined within-person effects of motives (effect-enhancement, social, offered [it was offered], coping) on number of negative consequences and on experiencing hangover, nausea, or blackout; and indirect effects via two concurrent mediators: using multiple alcohol products and multiple cannabis products. Total effect models showed effect-enhancement motives were related to nausea, social motives to number of total consequences and hangover, and coping motives to blackout. Effect-enhancement, social, and offered motives evinced significant indirect effects on consequence outcomes via multiple alcohol, but not cannabis, product use. Coping motives did not exhibit significant indirect effects, and were related to multiple cannabis, but not alcohol, product use, although all other motives were related to both mediators. Findings support recent work demonstrating within-person relations between social motives and negative consequences on SAM-use days. Limiting the number of alcohol products consumed on SAM-use days may be beneficial, particularly for young adults using to enhance intoxication or for social reasons.

### Public Significance Statement

This study suggests that college students who consume both alcohol and cannabis for social reasons may be at unique risk for negative consequences. Young adults who use alcohol and cannabis simultaneously to enhance intoxication, for social reasons, or because it was offered may benefit from recommendations to limit the number of alcohol products used on a given day to reduce the occurrence of physiological consequences.


**Keywords:** daily diary, simultaneous use, motives, alcohol, cannabis


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Simultaneous alcohol and marijuana (SAM) use is common in the U.S. (Metrik et al., 2018; Subbaraman & Kerr, 2015, 2020; Terry-McElrath & Patrick, 2018; Yurasek et al., 2017), particularly among college students (O'Hara et al., 2016; Sokolovsky et al., 2020;

White et al., 2019). Extant research has shown that significant risks are associated with using alcohol and cannabis simultaneously, relative to using either substance alone (Bailey et al., 2019; Earleywine & Newcomb, 1997), including higher levels of alcohol

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and cannabis consumption (Brière et al., 2011; Linden-Carmichael et al., 2019; Metrik et al., 2018; Subbaraman & Kerr, 2015), higher rates of alcohol use disorders (Midanik et al., 2007), and more negative consequences (e.g., hangover, nausea; Brière et al., 2011; Jackson et al., 2020; Linden-Carmichael et al., 2020; Subbaraman & Kerr, 2015; Yurasek et al., 2017). Other than examining the effects of volume of consumption (e.g., number of drinks) on consequences, however, little research has examined additional factors (e.g., motives) that may contribute to acute adverse outcomes of SAM use.

### Substance Use Motives

Substance use motives (i.e., social, enhancement, coping, and conformity) are robust predictors of substance use behavior with specific motives differentially predicting substance use behaviors and consequences (Cooper, 1994; Cooper et al., 1995; Cox & Klinger, 1988; for a review, see Cooper et al., 2016). Examination of specific motives in relation to alcohol-related consequences has found that coping motives are directly related to alcohol consequences (Cooper et al., 1995; Patrick et al., 2011), whereas the effect of enhancement motives on consequences is indirect through higher levels of drinking (Cooper et al., 1995; Merrill & Read, 2010; Read et al., 2003). Both cross-sectional and longitudinal studies have found alcohol coping motives to be directly associated with specific consequences including physiological dependence, academic/occupational consequences, risky behaviors, and poor self-care (Cooper et al., 1992; Merrill & Read, 2010; Merrill et al., 2014). On the other hand, drinking for social or conformity reasons has been shown to be less risky than drinking to cope or for enhancement reasons (see Cooper et al., 2016, for a review).

Patterns between cannabis use motives and consumption and consequences largely mirror the alcohol literature, such that externally focused motives (social, conformity) are unrelated or minimally related to cannabis use frequency, whereas internally focused motives (coping, enhancement) are associated with more frequent consumption (Cooper et al., 2016). Consistently, using cannabis to cope is robustly related to experiencing more cannabis problems, and using cannabis for enhancement reasons is indirectly related to problems via consumption (Cooper et al., 2016). As with using alcohol or cannabis alone, individuals engage in SAM use for different reasons, including using both substances to “cross-fade”—or to enhance intoxication (Patrick & Lee, 2018) or to offset the effects of the other drug (Patrick et al., 2018). These motives may also differentially relate to SAM-use outcomes (see also Conway et al., 2020).

Motives for substance use have mostly been examined cross-sectionally or prospectively over longer periods and are generally treated as trait-like (Cooper, 1994; Cooper et al., 1995; Cox & Klinger, 1988; White et al., 2018). More recent work on single substance use, however, has shown that alcohol and cannabis use motives vary day-to-day with significant within-person variation (Armeli et al., 2014, 2016; Bonar et al., 2017; Buckner et al., 2019; Ehrenberg et al., 2016; O’Hara et al., 2014). Only two studies have examined motives to use alcohol and cannabis simultaneously at the event- or daily-level. Patrick et al. (2019) showed that elevated enhancement and conformity motives were linked to simultaneous use, whereas elevated coping motives were associated with

cannabis-only use. In a follow-up study, Patrick et al. (2020) specifically examined cross-fading motives and found that these motives were linked to more alcohol, but not cannabis, consumption and to perceived intoxication on that day. Cross-fading motives also were related to positive, but not negative, consequences, whereas enhancement, social, coping, and conformity motives exhibited the following differential positive relations to consequences: enhancement motives with alcohol-related positive consequences; social motives with alcohol-related positive and negative consequences; conformity motives with alcohol-related negative consequences; and coping motives with cannabis-related positive and negative consequences (Patrick et al., 2020). These novel findings suggest that distinct SAM-use motives may differentially relate to specific consequences. However, this has yet to be tested.

### Manner of SAM Use

The manners in which young adults engage in simultaneous use may also be relevant to specific consequences, as existing work has shown that the ways individuals consume alcohol and cannabis can influence amount consumed and consequences. For example, the negative consequences of alcohol use preceding cannabis use (“green out” symptoms such as dizziness, nausea, and vomiting) point to the importance of ordering in combining alcohol and cannabis (Gunn et al., 2021). Beyond ordering, specific product use [type of product (e.g., leaf vs. concentrate or beer vs. liquor), number of products within a substance] can have implications for consequences. Indeed, harm-reduction strategies related to manner of drinking (e.g., avoid mixing types of alcohol, avoid taking shots) are robustly related to reduced drinking and negative consequences at both between- and within-person levels (Linden-Carmichael et al., 2018; Martens et al., 2007; Napper et al., 2014; Pearson et al., 2013). Though most studies have examined relations between these strategies and aggregated negative consequences, Linden-Carmichael et al. (2018) examined the influence of manner of drinking strategies on specific physiological negative consequences (e.g., hangover, passed out, bad physical shape the next day). Findings showed a within-person reduction in experiencing these physiological consequences on days when manner of drinking harm-reduction strategies was used. Similar harm-reduction strategies exist for manner of cannabis use, including avoiding cannabis concentrates as well as avoiding mixing cannabis with alcohol (Pedersen et al., 2017).

Despite recommending against multiple product use, almost no work has examined the day-level effects of multiple product use, particularly on co-use/simultaneous use days. To address this question, our research group compared 12 distinct alcohol and cannabis product combinations (e.g., liquor combined with leaf cannabis) used on a given co-use day and found that combinations involving multiple products within a substance use class (i.e., using two or more alcohol and/or cannabis products on a given day) were linked to greater odds of experiencing a negative consequence (Stevens et al., 2020a). This was the first study to corroborate specific recommendations currently reflected in harm-reduction strategies for manner of alcohol and cannabis use. However, no work has examined relations between multiple product use and specific consequences, which may reveal differential relations to inform future work in this area.

## Interplay of Motives and Manner of SAM Use

There is also a presumed link between motives and manner of use. Motives are thought to be the most proximal antecedent of the alcohol use event (Cox & Klinger, 1988) and thus alcohol outcomes are likely a function of both motives and manner of use on that day. Kuntsche et al. (2006) conducted the only study, to our knowledge, to examine motives and manner of drinking in a cross-sectional adolescent sample, with manner of use defined as the alcoholic beverage most consumed during their last drinking occasion but broadly construed as a person-level construct (e.g., “wine drinkers,” “spirit drinkers”). Findings showed differential relations between beverage preference and drinking motives, such that enhancement motives were positively related to preferences for beer and liquor and negatively to preferences for wine and alcopops; social motives were positively related to a preference for alcopops and negatively to wine, whereas conformity motives were positively related to a preference for wine and negatively to beer. Further, the authors sought to explain the association between overall beverage preferences and consumption and risky drinking through proximal drinking motives. The indirect effect of alcohol product preference via drinking motives was supported when beer was the preferred beverage. Similarly, relations between coping motives and risky drinking were amplified among adolescents who preferred liquor, relative to other beverage preferences. This work demonstrates the importance of both motives and product type on problematic alcohol use; however, this study retrospectively assessed beverage types consumed at the last drinking event to determine beverage preference and was limited to alcohol only. In addition, their definition of beverage preference (proportion of a specific beverage on the total amount of drinks consumed at the last drinking occasion) fails to consider the number of beverage types consumed on the occasion. For a given person on a given day, specific motives for simultaneous use may relate to the use of multiple alcohol and/or cannabis products, which, in turn, may be linked to specific negative consequences.

## Present Study

The purpose of the present study was two-fold: (a) to examine the day-level within-person effects of specific reasons for using alcohol and cannabis together on total number of negative consequences, and three specific physiological consequences, above and beyond consumption on that day (Aim 1) and (b) to determine whether these specific motives exhibit significant indirect effects on consequence outcomes via the number of alcohol products and number of cannabis products used on that day (Aim 2). To examine study aims, we analyzed data from a larger multi-site study of college students who used alcohol and cannabis simultaneously at least once in the past month, which included two bursts of 28 days of data collection with five repeated surveys each day. To address Aim 1, we examined the total effects of specific motives on the number of negative consequences experienced on that day. We then used a similar approach to examine the three distinct physiological consequences as outcomes. Given that no work, to our knowledge, has examined nuanced relations between specific simultaneous alcohol and cannabis use motives and individual negative consequences, we selected four motives and four consequence outcomes a priori that may be particularly relevant to multiple product use. The motives

examined included effect-enhancement (cross-fading), social, offered [it was offered], and coping motives, and the outcomes of interest were total number of negative consequences and three specific consequences (i.e., experiencing a hangover, nausea, or a blackout).

To address Aim 2, we then examined the number of alcohol products and number of cannabis products used on that day as two concurrent mediators of relations examined in Aim 1. Indeed, multiple product use may be intentional to achieve a desired level of intoxication (as captured by effect-enhancement and coping motives), or it may be opportunistic and reflect one’s context and product accessibility on that day (as measured by social and offered motives). Consistent with similar work (Linden-Carmichael et al., 2018), use of multiple alcohol and/or cannabis products also may predict more physiological consequences, such as experiencing a hangover, nausea, or a blackout.

Given that no work has examined these nuanced constructs together at the daily level, particularly in a mediation model (Aim 2), the present study is largely exploratory; we do not proffer specific hypotheses for differential relations examined in Aim 1. For Aim 2, we generally expected to find within-person indirect effects via multiple product use but particularly through alcohol products, given that young adults tend to attribute their acute consequences on SAM occasions to alcohol rather than to cannabis use (Jackson et al., 2020).

## Materials and Methods

### Design and Sample

#### Screening Survey

Full-time college students (ages 18–24) were recruited to participate in a larger parent study on SAM use from universities in three states with varying recreational cannabis policies. Eight thousand students were randomly selected from each university’s registrar database stratified by expected year of graduation (total  $N = 24,000$ ) and were emailed an invitation to participate in an online screener. Screening completers ( $N = 7,000$ ) included more women, more White students, fewer Black students, more Asian students, more Hispanic/Latinx students, and younger students (i.e., ages 18–21); effect sizes for these differences were small (Cohen’s  $h = .07-.26$ ). Of those screened, 2,874 (41.1%) were considered eligible to participate (i.e., between ages 18 and 24, enrolled full-time in one of the three universities, endorsed past-year alcohol and cannabis use). Students who completed the screening survey were eligible for several lotteries to win \$100 (10 lotteries per school). See White et al. (2019), Sokolovsky et al. (2020), and Stevens et al. (2020b) for further details regarding screening for the parent study.

#### Baseline Survey

Of students eligible for the parent study, a random sample of 2,501 students (stratified by university) was invited via email to participate in the parent study’s baseline survey, and 1,524 (60.9%) invitees completed the baseline survey. We retained the data for 1,390 (91.2%) of these students after excluding participants who provided responses inconsistent with baseline survey eligibility criteria (e.g., inconsistent reporting of past-year alcohol and

cannabis use) and whose surveys had technological problems/did not complete the baseline survey. See White et al. (2019) and Stevens et al. (2020b) for further details regarding the baseline survey of the parent study. Three months later students completed a follow-up survey. Participants were compensated \$25 for the baseline survey and \$35 for the follow-up survey.

### Daily Survey

Of those who completed the baseline survey, 693 used alcohol and cannabis at the same time “so that their effects overlapped” (i.e., SAM use) within the past month, deeming them eligible to participate in the repeated daily survey (RDS) phase. Invited participants ( $N = 596$ ) were stratified based on frequency of past-month SAM use and sex assigned at birth. A cap was placed on each category for sex and SAM use within each school (i.e., recruitment site), such that more frequent SAM users (i.e., three or more times in the past month) were oversampled to ensure sufficient base rates of SAM use in the RDS phase. Likewise, male participants were oversampled to achieve more of a balance between male and female participants in the RDS phase. The other 97 students were not invited due to pre-established quotas. Enrollment for this phase was conducted on a rolling basis until quotas were filled; therefore, not all of those invited could be enrolled in the daily phase even if they responded. Of the 379 students who were given access to the custom-designed mobile application used for this phase, 343 (90.5%) ultimately were enrolled in this portion of the study.

Data collection directly followed the longer surveys (baseline and three-month follow-up) and comprised 28 days of RDS at each burst (two bursts resulting in 56 total days). Surveys were prompted at 9:00 a.m., 2:00 p.m., 5:00 p.m., 8:00 p.m., and 11:00 p.m. daily using a custom smartphone application (see Stevens et al., 2020b, for details). For the first survey of the day prompted at 9:00 a.m., students were also asked additional questions assessing yesterday’s behavior. Participants were provided 4 hr to complete the 9:00 a.m. survey and 2 hr to complete all other surveys. The 9:00 a.m. survey replaced the 2:00 p.m. survey for participants who did not complete the 9:00 a.m. survey by that time. See Stevens et al. (2020b; Supplemental Materials) for more details regarding the parent study. Reminders were provided to participants 15 min before surveys closed. Participants were compensated \$1 for each completed daily survey, with weekly and overall bonuses to encourage high response rates. See Stevens et al. (2020b) and Sokolovsky et al. (2020) for additional details regarding the parent study’s RDS bursts. Aggregated across the five RDS, 88.4% of participants completed at least one survey daily, and mean morning survey compliance equaled 81.9%. Both compliance rates exceed the pooled compliance rate shown in a recent meta-analysis on EMA and substance use (Jones et al., 2019). As a part of the parent study, all participants were trained on standardized drink equivalences set forth by the National Institute of Alcoholism and Alcohol Abuse (National Institute on Alcohol Abuse and Alcoholism [NIAAA], 2007). All procedures were approved by the coordinating university’s Institutional Review Board. A Certificate of Confidentiality was obtained from the National Institute on Drug Abuse.

We retained data from 54 study days due to technical difficulties that occurred during the first two study days. Excluding two participants who only completed the first two study days, the final

RDS sample comprised 341 students. Among these students (53% women;  $M_{\text{age}} = 19.79$ ; 74% White, 11% Asian, 9% bi- or multi-racial, 3% Black, 0.7% American Indian, 0.2% Pacific Islander, 2% other race; 10% Hispanic/Latinx), 32.3% of students were from School A (in a state where recreational cannabis use is illegal), 34.1% from School B (in a state where recreational cannabis use is decriminalized), and 33.5% from School C (in a state where recreational cannabis use is legal for adults 21 and older). Most study days were non-use days ( $n = 7,781$ ; 49%), followed by cannabis-only days ( $n = 3,917$ ; 25%), alcohol-only days ( $n = 2,076$ ; 13%), SAM days (i.e., using alcohol and cannabis together, within 3 hr or so that their effects overlapped;  $n = 1,844$ ; 12%), and concurrent use days (i.e., alcohol and cannabis used on the same day but not so that their effects overlapped;  $n = 180$ ; 1%). In the present study, our analytic sample was restricted to participants reporting any day of SAM use across the 54 days ( $n = 1,844$  days), which resulted in an analytic sample of 281 students (58% women;  $M_{\text{age}} = 20.17$ ; 79% White, 10% Asian, 6% bi- or multi-racial, 3% Black, 0.2% Pacific Islander, 2% other race; 7% Hispanic/Latinx).

## Measures

### Demographics

Participants self-reported demographic information at the baseline survey, including age (continuous) and sex assigned at birth (“1” for male, “0” for female).

### Motives

At each RDS following the endorsement of SAM use, participants were asked, “What motivated you to drink and use marijuana between [time X] and [time Y]?” The timeframe for each motives question was from the time the previous survey was submitted to the time the current survey was begun. Participants were instructed to select all motives for drinking and using cannabis from the following list: “to be social” (48% of SAM-use days), “to cope” (13%), “it was offered” (30%), “to have fun” (86%), “to fit in” (3%), “expand awareness” (10%), “get higher from another drug” (5%), and “was too high from other drug” (1%). As part of the parent study, motives were selected from a psychometrically valid measure of co-use/simultaneous use motives (Patrick et al., 2018) as well as two well-validated measures of alcohol (Drinking Motives Questionnaire Revised, Cooper, 1994) and cannabis (Marijuana Motives Measures, Simons et al., 1998) use motives. Each type of motive was dichotomized at the daily level. Daily-level endorsement of a motive occurred if a participant endorsed that motive on at least one RDS on that day.

### Alcohol Products

At each RDS following endorsement of alcohol use (see *Covariates* below), participants were asked, “What type of alcohol had you been drinking between [time X] and [time Y]?” Options included “beer” (no/yes), “wine” (no/yes), “liquor” (no/yes), and “beer alternative” (no/yes). Each individual product (beer, beer alternative, liquor, beer) was dichotomized at the daily-level, such that a participant was coded as a “yes” for using a given product if they endorsed using this product on at least one RDS. A sum of the

number of alcohol products endorsed across the day was then used in all analyses (range = 1–4).

### **Cannabis Products**

At each RDS survey following endorsement of cannabis use (see *Covariates* below), participants were asked, “In what form was the marijuana you used between [time X] and [time Y]?” Options included “dry leaf” (no/yes), “concentrate” (no/yes), and “edible” (no/yes). For the present study, number of cannabis products (i.e., sum) was examined. An analogous procedure (as was used for alcohol products) was used for aggregating individual cannabis products to the daily level (range = 1–3).

### **Negative Consequences**

On the morning survey following a SAM-use day, participants indicated whether the following consequences occurred “because of yesterday’s use of alcohol and marijuana together”: hangover (19% of SAM-use days), nausea/vomiting (7%), hurt self (1%), drove car drunk/high (7%), blackout (4%), rude/aggressive (1%), and unwanted sex (0.5%). As part of the parent study, we considered consequences across several validated measures, including the Brief Young Adult Alcohol Consequence Questionnaire (Kahler et al., 2005), Brief Marijuana Consequences Questionnaire (Simons et al., 2012), Young Adult Alcohol Consequences Questionnaire (Read et al., 2006), Rutgers Alcohol Problem Index (White & Labouvie, 1989), and the Rutgers Marijuana Problem Index (White et al., 2005), selecting acute consequences that we expected to vary day-to-day. As part of the present study, we examined the total number (0–7) of consequences on a given day as the primary outcome ( $M = 0.40$ ,  $SD = 0.62$ ) and explored the following three specific physiological consequences: nausea (yes/no), hangover (yes/no), and blackout (yes/no). We focused on these three physiological consequences as they were expected to be relevant to multiple product use, particularly for alcohol (see Linden-Carmichael et al., 2018).

### **Covariates**

In addition to adjusting for demographic information (i.e., age, sex [male vs. female] and school [recruitment site; School A, School B vs. School C]), we included weekend (i.e., Friday and Saturday vs. weekday [Sunday–Thursday]), use of other drugs (“Did you use any drugs other than marijuana between [time X] and [time Y]?”; yes vs. no), number of drinks consumed on a given day, and number of cannabis uses on a given day as covariates. Participants indicated the number of drinks consumed since their last RDS using a graphical interface, tapping on the timeline at each specific time a drink was consumed (see Stevens et al., 2020b, Supplemental Materials, for screenshots): “Tap your finger in the blue box each time you had a drink at the corresponding time.” The sum of drinks reported at each RDS determined the total number of drinks reported on that day. An analogous procedure was used for number of cannabis uses, such that participants were asked to tap the same graphical interface at each specific time they used cannabis. The sum of these taps reported at each RDS determined the total number of cannabis uses reported on that day. As a sensitivity analysis, we ran all models including burst (one vs. two) as a covariate. Model

effects remained unchanged; thus, for parsimony, we did not retain this covariate.

### **Analytic Strategy**

Data management was conducted in SAS 9.4™ software (SAS Institute Inc, 2013). For the present study, we aggregated all RDS to the daily level to match the level of analysis of negative consequences (assessed once daily at 9:00 a.m. for the day before). All analyses were restricted to SAM-use days ( $n$  observations = 1,844) nested within 281 students. Seventy-seven percent of SAM-use days included full data coverage of the day for a given participant; the remaining 23% of days had incomplete coverage of the day, with two or more consecutive surveys missed by a participant on that day. Thus, there were some missing data on incomplete coverage days, which were handled using estimation procedures in Mplus (see below for details). All measures, data exclusions, and sample size determinations pertinent to the present study (in which data were drawn from a larger parent study) have been described in the *Measures* and/or *Analytic Strategy*.

### **Total Effects (Aim 1)**

We first tested the within-person total effects of each Level-1 motive (effect enhancement, social, offered, coping) on each Level-1 consequence outcome (number of negative consequences, nausea, hangover, and blackout) using multilevel modeling in Mplus version 8.2 (Muthén & Muthén, 2019). This approach disentangles within-person (Level-1) from between-person (Level-2) effects by person-mean centering the Level-1 effect and adding the person-mean of each Level-1 variable at Level-2 (Curran & Bauer, 2011; Preacher et al., 2010; Zhang et al., 2009). The Bayes estimator was used for missing data, which uses non-informative priors and uses full information, like maximum likelihood estimation (Muthén, 2010). All total effect models included Level-2 covariates (age, sex, school) and Level-1 covariates (weekend vs. weekday, number of drinks, number of cannabis uses, other drug use).

### **Indirect Effects (Aim 2)**

We then used multilevel mediation in Mplus to examine the within-person indirect effects of each motive (Level-1) on number of negative consequences (Level-1) via number of alcohol products (Level-1) and number of cannabis products (Level-1) as concurrent mediators. In 12 additional models, we considered three specific physiological consequences (hangover, nausea, blackout) as outcomes for each motive. Indirect effects were tested regardless of the statistical (non)significance of the total effects examined in Aim 1, consistent with contemporary approaches to mediation (Hayes, 2009; MacKinnon et al., 2002; Rucker et al., 2011). Consistent with Aim 1 models, our analytic procedure disaggregated within-from between-person effects. Indirect effects were computed using a product-of-coefficients approach using MODEL CONSTRAINT (Zhang et al., 2009). Multilevel mediation models adjusted for the same covariates included in Aim 1 models.

As recommended by Muthén (2010) for Bayesian estimation, model convergence was determined by the Potential Scale Reduction (PSR), with PSR values closer to 1.0 indicating model convergence. For each mediation model, we increased the number of iterations and examined

whether the PSR value remained close to 1.0, which corroborates initial model convergence (Muthén, 2010). All models reached convergence using 10,000 iterations. See Supplemental Table S1 for PSR information across iterations for all mediation models.

## Results

Students consumed five drinks ( $SD = 4.54$ ) and used cannabis five times ( $SD = 6.65$ ), on average, on each SAM-use day; other drug use was minimal in this sample (9% of SAM-use days). Of the SAM-use days analyzed in the present study, two other drug use days (1% of 194 other drug use days) involved “other amphetamines,” 100 other drug use days (52%) involved cocaine, 53 other drug use days (27%) involved Ritalin/Adderall, 3 other drug use days (2%) involved opioids, 11 other drug use days (6%) involved sedatives, 12 other drug use days (6%) involved hallucinogens, 2 other drug use days (1%) involved ecstasy, and 24 other drug use days (12%) involved “other drugs.” See Table 1 for descriptive statistics of alcohol products and cannabis products used on SAM days, including alcohol product combinations and cannabis product combinations.

### Total Effects (Aim 1)

#### Effect-Enhancement Motives

After accounting for alcohol and cannabis consumption on a given day, in addition to other covariates, effect-enhancement motives were only significantly related to experiencing nausea; relations to other consequence outcomes and total number of consequences were not significant (see *c* paths; Figure 1a–d).

**Table 1**

*Descriptive Statistics of Alcohol Product Combinations and Cannabis Product Combinations Used on SAM Days (n = 1,844 days)*

Product/combination of products	<i>n</i> observations (%)
Products used on SAM days	
Liquor	1,031 (55.91%)
Beer	990 (53.69%)
Beer alternative	137 (7.43%)
Wine	434 (23.54%)
Leaf	1,526 (82.75%)
Concentrate	478 (25.92%)
Edible	88 (4.77%)
Product combinations used on SAM days	
Liquor + beer	428 (23.21%)
Liquor + beer alternative	80 (4.34%)
Liquor + wine	153 (8.30%)
Beer + beer alternative	51 (2.77%)
Beer + wine	128 (6.94%)
Wine + beer alternative	23 (1.25%)
Liquor + beer + beer alternative	40 (2.17%)
Liquor + beer + wine	58 (3.15%)
Liquor + beer alternative + wine	15 (0.81%)
Beer + beer alternative + wine	13 (0.70%)
Liquor + beer + beer alternative + wine	11 (0.60%)
Leaf + concentrate	205 (11.12%)
Leaf + edible	37 (2.01%)
Concentrate + edible	17 (0.92%)
Leaf + concentrate + edible	11 (0.60%)

*Note.* SAM = simultaneous alcohol and marijuana.

### Social Motives

Social motives were significantly associated with number of consequences and experiencing a hangover on a given day after adjusting for consumption on that day and other covariates; relations between social motives and both nausea and blackout were not significant (see *c* paths; Figure 2a–d).

### Offered Motives

Total effects from offered motives to consequence outcomes were not significant after accounting for consumption on that day and other covariates (see *c* paths; Figure 3a–d).

### Coping Motives

Coping motives were significantly related to experiencing a blackout after adjusting for consumption on that day and other covariates. Relations to other consequences and number of consequences were not significant (see *c* paths; Figure 4a–d).

### Indirect Effects (Aim 2)

Level-1 path estimates (*a* paths, *b* paths, *c'* paths) from each mediation model are provided in Figures 1–4. Direct effects (*c'* paths) are reported in Figures 1–4 but not discussed or evaluated to determine mediation (cf. Baron & Kenny, 1986), given we assessed indirect effects (using a product-of-coefficients approach) consistent with contemporary mediation recommendations (see *Analytic Strategy* for details). Level-1 indirect effects and their 95% credibility intervals are provided in Table 2. Between-person (Level-2) indirect effects are provided in Table 2 but not discussed in text given our focus on within-person (Level-1) effects.

### Effect-Enhancement Motives

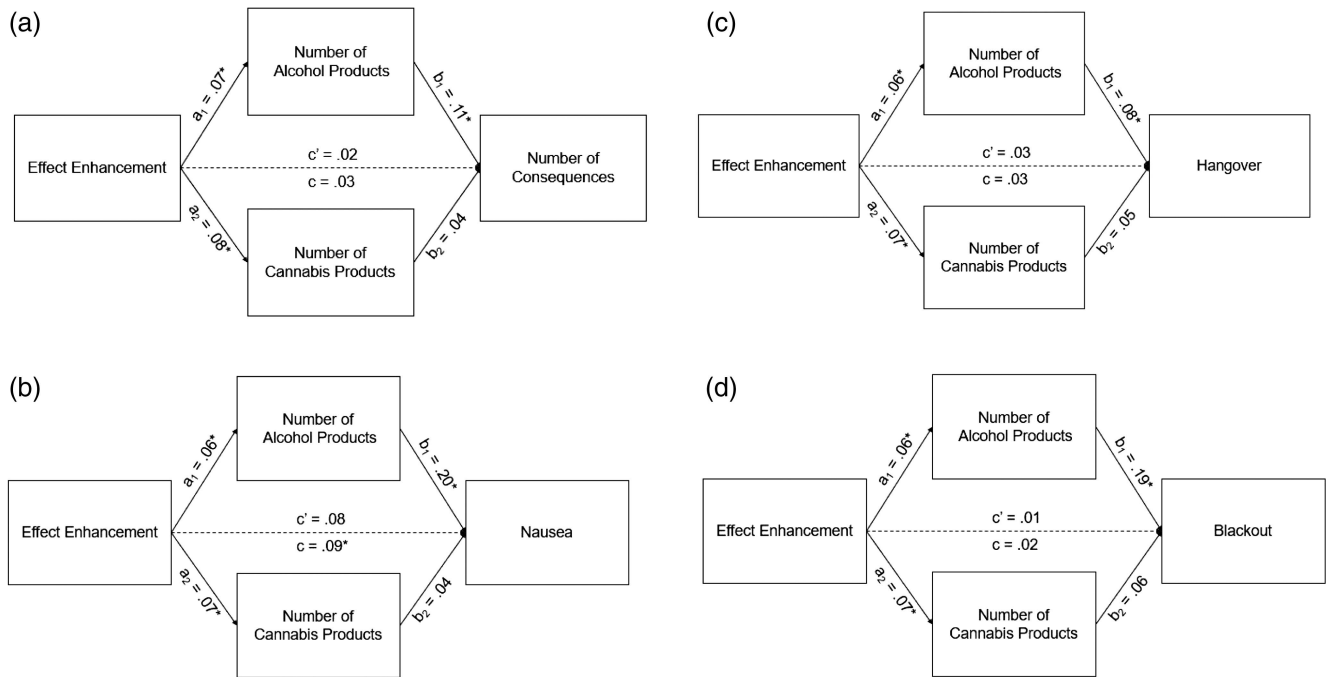
Over and above alcohol and cannabis consumption, effect-enhancement motives exhibited statistically significant within-person indirect effects on number of consequences, as well as experiencing nausea, hangover, and blackout on a given day, via the number of alcohol products, but not the number of cannabis products, consumed on that day (see Table 2 for indirect effects). Specifically, for each consequence outcome, the endorsement of effect-enhancement motives exhibited a positive within-person relation to number of alcohol products (*a*<sub>1</sub> paths), which, in turn, demonstrated a positive within-person relation to consequences (*b*<sub>1</sub> paths), after adjusting for age, sex, school, weekend (vs. weekday), alcohol consumption, cannabis consumption, and other drug use. The paths (*a*<sub>2</sub>) from effect-enhancement motives to number of cannabis products were statistically significant, though number of cannabis products (*b*<sub>2</sub> paths) was not significantly related to consequence outcomes (see Figure 1a–d).

### Social Motives

After accounting for alcohol and cannabis consumption, as well as other covariates, social motives exhibited statistically significant within-person indirect effects on number of consequences, nausea, and blackout via the number of alcohol products consumed on that day, but not the number of cannabis products consumed.

**Figure 1**

Level-1 Path Estimates From Effect-Enhancement Motives to Number of Consequences, Hangover (Yes/No), Nausea (Yes/No), and Blackout (Yes/No) via Number of Alcohol Products and Number of Cannabis Products. Level-2 Path Estimates Were Modeled but Not Presented for Simplicity



The c path reflects the total effect, and the c' path represents the direct effect after including mediator variables. All models included alcohol consumption, cannabis consumption, weekend (vs. weekday), and other drug use as Level-1 covariates, as well as age, sex, and school as Level-2 covariates; these covariates were not presented for simplicity.

\*  $p < .05$ .

This indirect effect, however, was not significant when examined for hangover (see Table 2). In all models, the  $a_1$  paths between social motives and number of alcohol products were positive and statistically significant. The  $b_1$  paths between number and alcohol products and number of consequences, nausea, and blackout also were positive and statistically significant; however, the  $b_1$  path to hangover was not, which explains the nonsignificant indirect effect for the social motives-hangover model. The  $a_2$  paths from social motives to number of cannabis products were all positive and statistically significant; however, the  $b_2$  paths from number of cannabis products to consequence outcomes were not (see Figure 2a–d).

### Offered Motives

Offered motives demonstrated significant within-person indirect effects on all consequence outcomes via the number of alcohol products consumed on that day, but not through the number of cannabis products consumed, after adjusting for alcohol and cannabis consumption and other covariates (see Table 2). All  $a_1$  and  $b_1$  paths through number of alcohol products were positive and statistically significant; only the  $a_2$  paths from offered motives to number of cannabis products were positive and significant, whereas the  $b_2$  paths to consequence outcomes were not (see Figure 3a–d).

### Coping Motives

By contrast to the other tested motives, coping motives did not exhibit significant within-person indirect effects on the four consequence outcomes via the number of alcohol products or the number of cannabis products consumed on that day (see Table 2). Specifically, the  $a_1$  paths from coping motives to number of alcohol products were not significant; however, in this case, only the  $a_2$  paths from coping motives to number of cannabis products were positive and statistically significant. As with the earlier models, the  $b_1$  paths but not the  $b_2$  paths to consequence outcomes were positive and statistically significant (see Figure 4a–d).

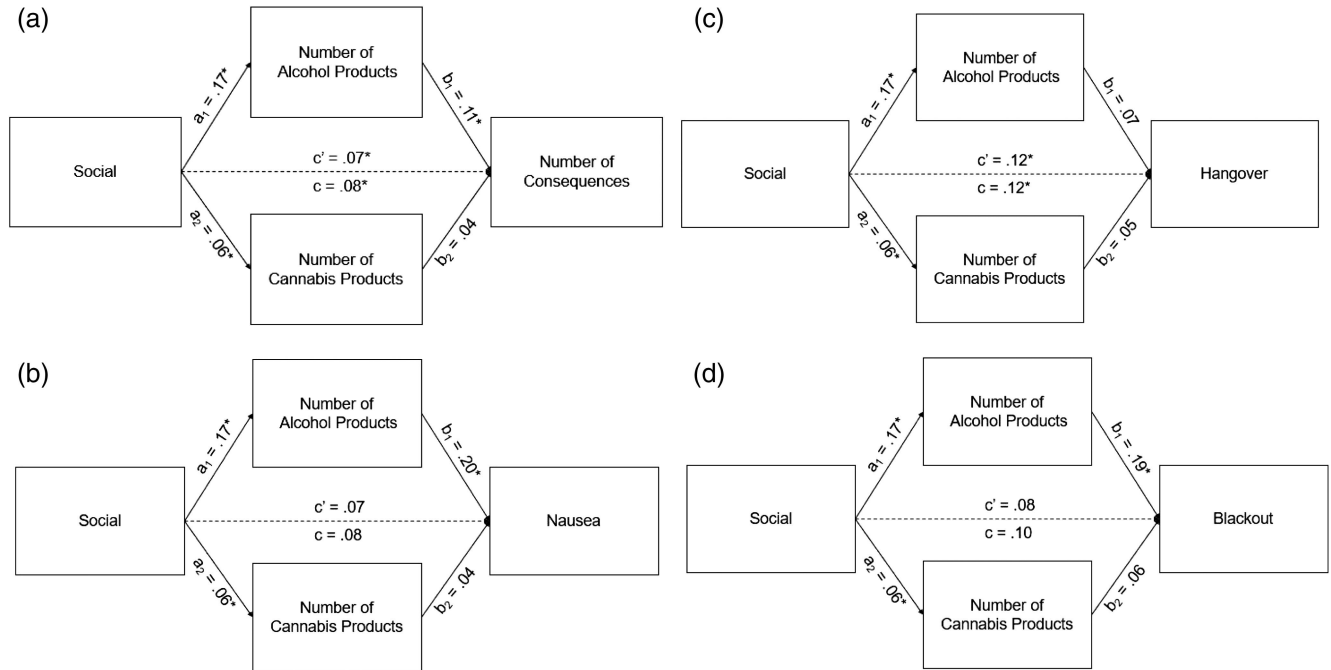
### Discussion

The present study examined two novel aims that (a) elucidated nuanced day-level within-person relations between specific motives and negative consequences on SAM days, over and above consumption on that day and (b) determined whether these specific motives exhibit indirect effects on consequence outcomes via the number of alcohol products and/or the number of cannabis products used on that day. This study aims provided a fine-grained examination of specific motives and consequences on SAM days, which has yet to be conducted at this level of specificity, and



**Figure 2**

Level-1 Path Estimates From Social Motives to Number of Consequences, Hangover (Yes/No), Nausea (Yes/No), and Blackout (Yes/No) via Number of Alcohol Products and Number of Cannabis Products. Level-2 Path Estimates Were Modeled but Not Presented for Simplicity



The c path reflects the total effect, and the c' path represents the direct effect after including mediator variables. All models included alcohol consumption, cannabis consumption, weekend (vs. weekday), and other drug use as Level-1 covariates, as well as age, sex, and school as Level-2 covariates; these covariates were not presented for simplicity.

\*  $p < .05$ .

highlighted the importance of multiple alcohol product use on a given day as a potential intervention target (depending on the reason for SAM use). For Aim 1, after accounting for alcohol and cannabis consumption on that day, effect-enhancement motives were directly related to experiencing nausea, social motives were related to total number of consequences and experiencing a hangover, offered motives were not significantly related to consequence outcomes, and coping motives were related to experiencing a blackout. For Aim 2, apart from the social motives-hangover model, we found strong support for within-person indirect effects of effect-enhancement, social, and offered motives on the four consequence outcomes through the number of alcohol products consumed on that day, but not the number of cannabis products consumed. By contrast, coping motives exhibited no significant indirect effects on consequences via the number of alcohol products or via the number of cannabis products consumed on that day. Taken together, aside from some notable exceptions (discussed below), our findings suggest relatively few direct within-person relations between specific motives and consequences once accounting for consumption on that day, but rather that these specific motives, with the exception of coping motives, seem to influence multiple alcohol product use on a given SAM-use day, which then places individuals endorsing these specific reasons for use at greater risk for negative consequences, including experiencing a hangover, nausea, and/or blackout.

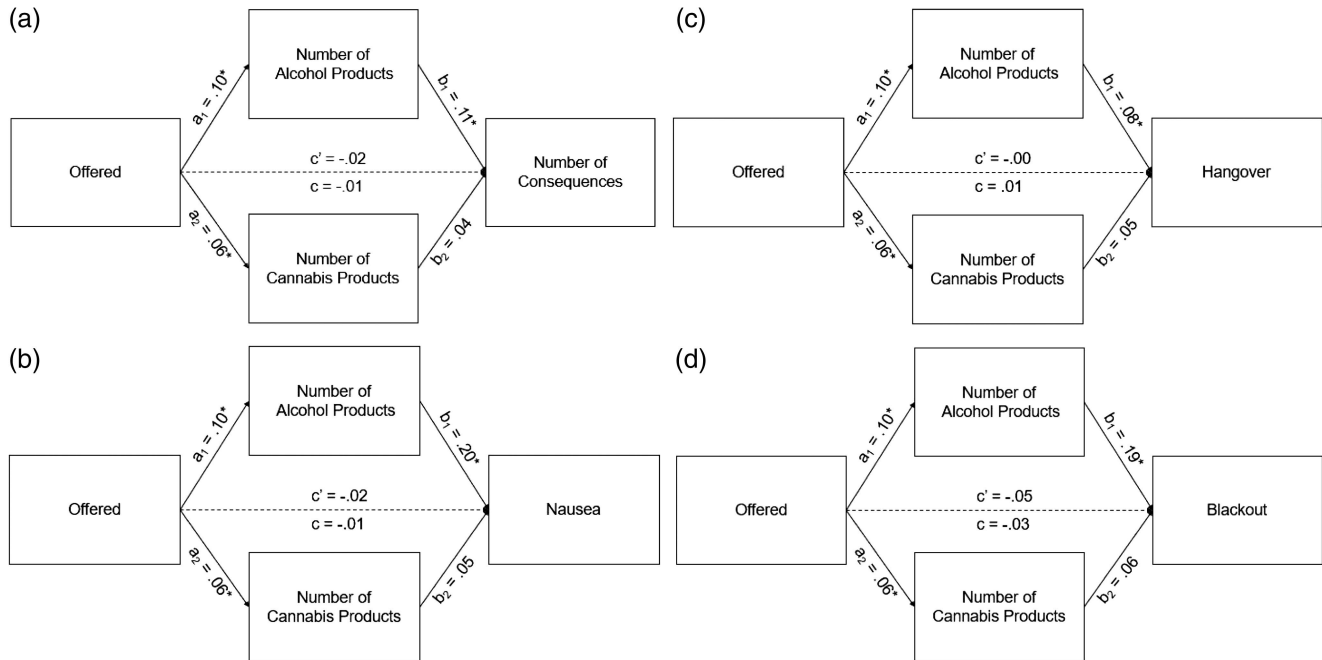
### Aim 1: Total Effects: Day-Level Motives and Consequences

We found that days where students sought to get higher/more intoxicated from SAM use resulted in greater nausea, adjusting for the actual amount of alcohol and cannabis consumed on that day; the same was not true for either hangover or blackout or a composite of all negative consequences. This is mostly consistent with Patrick et al. (2020) who also found that cross-fading motives were not associated with alcohol-related negative consequences at the daily level, although they were associated with positive consequences in Patrick et al. (2020), which were not examined in the present study. Building off this initial work, our findings highlight the utility of examining the specificity between individual motives and consequences on SAM-use days, as analyzing negative consequences in aggregate may mask specific relations between individual motives and specific consequences.

We are the first, to our knowledge, to examine relations between offered motives—a less deliberate and more opportunist reason for SAM use—and individual consequences; we found that this motive was not significantly related to consequences once accounting for consumption. This is somewhat surprising given that college student substance use is often opportunistic, and their alcohol and cannabis consumption is strongly associated with the availability of each substance (e.g., Schuermeyer et al., 2014; von Sydow et al., 2002; Wechsler & Nelson, 2008; Yacoubian, 2007) and offers of alcohol

**Figure 3**

Level-1 Path Estimates From Offered Motives to Number of Consequences, Hangover (Yes/No), Nausea (Yes/No), and Blackout (Yes/No) via Number of Alcohol Products and Number of Cannabis Products. Level-2 Path Estimates Were Modeled but Not Presented for Simplicity



The  $c$  path reflects the total effect, and the  $c'$  path represents the direct effect after including mediator variables. All models included alcohol consumption, cannabis consumption, weekend (vs. weekday), and other drug use as Level-1 covariates, as well as age, sex, and school as Level-2 covariates; these covariates were not presented for simplicity.

\*  $p < .05$ .

(e.g., Borsari & Carey, 2001; Cullum et al., 2012; Wood et al., 2001). Little work has examined cannabis offers outside of adolescent samples (e.g., Ellickson & Hays, 1992; Siegel et al., 2015), though, and more research is needed on cannabis offers among young adults, particularly during SAM-use occasions, to determine whether offered motives differentially relate to consumption versus consequences.

Of the four tested motives, using alcohol and cannabis simultaneously for social reasons was the most frequently endorsed. On days when students were motivated to engage in SAM use socially, they endorsed a greater total number of negative consequences and an increased likelihood of experiencing a hangover, but not nausea or blackout, over and above consumption on that day. This is consistent with Patrick et al. (2020) and indicates a potentially robust within-person association between simultaneous use social motives and negative consequences at the daily level. This notion, however, is counter to the alcohol-only and cannabis-only motives literature, which shows consistently weak relations between social motives and negative consequences (Cooper et al., 2016, for a review). Together with Patrick et al. (2020), these findings support a different relationship between SAM use and specific motives compared to single substance use (e.g., alcohol) and specific motives.

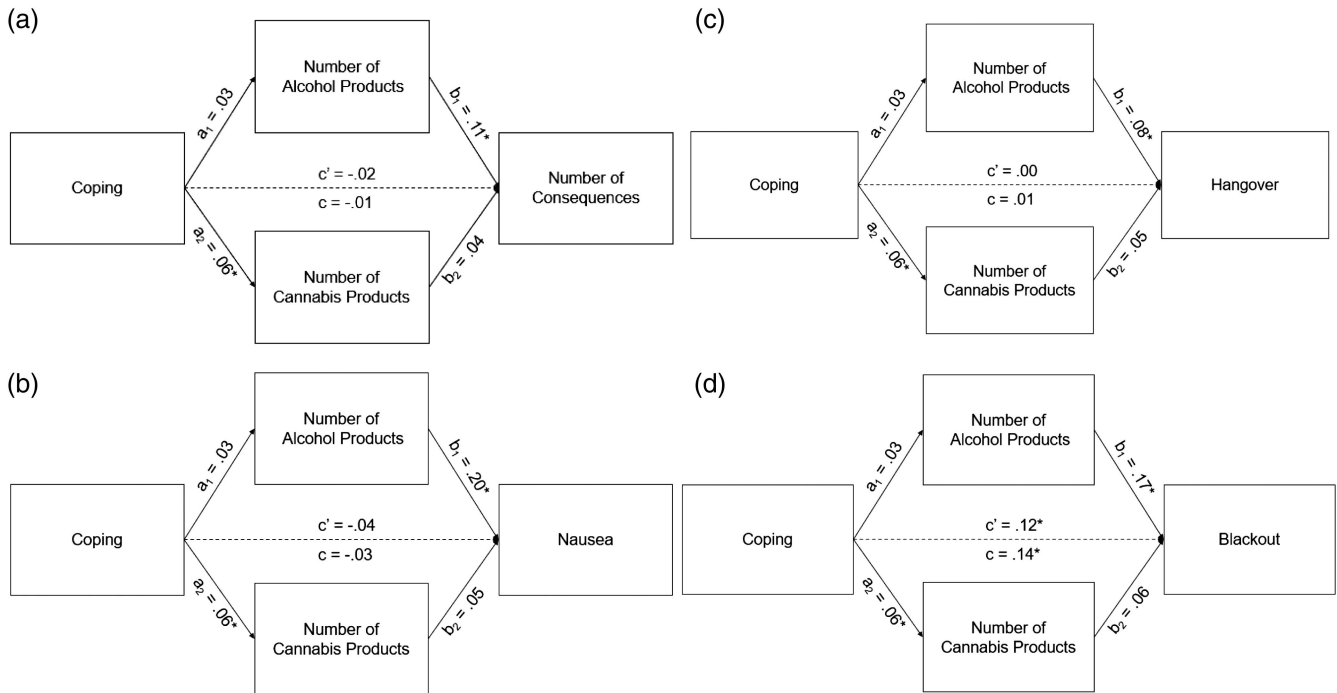
Engaging in SAM use to cope was related to experiencing a blackout on a given day, after adjusting for alcohol and cannabis consumption on that day, but not to nausea, hangover, or the aggregated consequences measure. This is somewhat congruent

with Patrick et al. (2020) who also did not find significant within-person relations between coping motives for simultaneous use and an aggregated measure of alcohol-related problems. On the other hand, they did find a significant association with an aggregated measure of cannabis-related problems (e.g., had difficulty concentrating, felt lethargic or sedated). Indeed, most consequence items included in the larger parent study are more reflective of alcohol-related, rather than cannabis-related, negative consequences, which could explain the mostly null total effects for coping motives found here. On the other hand, in the alcohol literature, between-person effects of coping motives and negative consequences have been incredibly robust (see Cooper et al., 2016), and one might expect to find a similar relation at the within-person level, though little work has tested this notion.

Though motivational models of substance use are conceptualized at the within-person level, substance use motives are typically analyzed at the between-person level (e.g., Simons et al., 2005; see Kuntsche et al., 2005; see also Cooper et al., 2016). However, within-person and between-person processes are not inherently the same (i.e., ecological fallacy; see Curran & Bauer, 2011). In fact, at the between-person level, externally focused drinking motives (e.g., social motives), relative to internally focused motives (e.g., coping motives), are generally considered less risky because drinking in social settings tends to be linked to fewer and/or less severe consequences than drinking alone, which is associated with greater suicidal ideation and greater odds of having problems with authorities as compared to drinking in social settings (e.g., Christiansen et al., 2002; Gonzalez et al., 2009). Alcohol

**Figure 4**

Level-1 Path Estimates From Coping Motives to Number of Consequences, Hangover (Yes/No), Nausea (Yes/No), and Blackout (Yes/No) via Number of Alcohol Products and Number of Cannabis Products. Level-2 Path Estimates Were Modeled but Not Presented for Simplicity



The c path reflects the total effect, and the c' path represents the direct effect after including mediator variables. All models included alcohol consumption, cannabis consumption, weekend (vs. weekday), and other drug use as Level-1 covariates, as well as age, sex, and school as Level-2 covariates; these covariates were not presented for simplicity.

\*  $p < .05$ .

use driven by external and potentially opportunistic motives is often more variable than use motivated by internal and likely intentional reasons, which also may explain the robust between-person relation between drinking to cope and negative consequences found in prior alcohol research (Cooper et al., 2016). Notably, a recent study found that drinking to cope was related to negative consequences at the between-person, but not within-person, level (Cook et al., 2020)—corroborating findings from the present study. Taken together, these findings suggest that engaging in SAM use for social reasons may be particularly risky for same-day negative consequences, whereas using alcohol only or in combination with cannabis to cope on a given day is not necessarily riskier for same-day negative consequences (except for blackout). Indeed, the risks associated with coping motives likely result from the frequency of using to cope for a given person.

We are the first, to our knowledge, to demonstrate a within-person direct relation between coping motives and the likelihood of experiencing a blackout above and beyond consumption. This finding is largely consistent with the limited existing literature in this area and in line with the notion that internal reasons for use often lead to more problematic outcomes (see Cooper et al., 2016). Specifically, a recent qualitative analysis of Twitter data showed that intentions to blackout were often discussed in the context of drinking for coping reasons (e.g., to manage stress; Riordan et al., 2019). In a mixed-methods study of college students, coping motives also were the most commonly cited reason for intending to blackout in the past 30 days (Miller et al., 2020).

However, a recent alcohol-only study did not find a significant within-person relation between coping (drinking) motives and blackout (Merrill et al., 2019), though important methodological differences may explain this disparate relation, including sample characteristics (SAM users vs. primarily alcohol-only users) and the assessment of motives (broad coping motives vs. disaggregated drinking coping motives for depression and anxiety). Thus, emerging research indicates that coping motives may be particularly relevant to experiencing a blackout, including on SAM-use days, but more research is needed to determine the replicability of this within-person relation.

Research examining relations between motives and consequences on SAM-use days is in its nascent stages as is research examining drinking motives and outcomes at the within-person (vs. between-person) level—and both have potential implications for theoretical motivational models of substance use. Indeed, coupled with Patrick et al. (2020), our findings suggest that motives specific to simultaneous use (e.g., effect-enhancement/cross-fading) should be integrated into motivational models that currently reflect a four-factor theoretical model developed from research on mono-substance use (Cooper et al., 2016). Moreover, associations of motives for use with consumption and consequences have most often been assessed at the between-person level; our findings along with others (e.g., Cook et al., 2020; O'Hara et al., 2015) suggest that our theoretical understanding of motives and outcomes (e.g., consumption, consequences) may not apply at the within-person level. Though speculative, this explanation is consistent with our

**Table 2***Indirect Effects of Co-Use Motives on Co-Use Consequences via Multiple Alcohol and Cannabis Product Usage*

Outcome/mediator	Effect enhancement motives		Social motives		Offered motives		Coping motives	
	IE	95% CI	IE	95% CI	IE	95% CI	IE	95% CI
Level-1 effects								
Number of consequences								
# of alcohol products	0.02*	[0.007, 0.041]	0.03*	[0.014, 0.039]	0.02*	[0.008, 0.029]	0.01	[-0.003, 0.023]
# of cannabis products	0.01	[-0.001, 0.022]	0.00	[0.000, 0.009]	0.00	[0.000, 0.010]	0.01	[0.000, 0.015]
Nausea								
# of alcohol products	0.07*	[0.022, 0.148]	0.09*	[0.047, 0.144]	0.06*	[0.027, 0.102]	0.03	[-0.009, 0.082]
# of cannabis products	0.02	[-0.023, 0.063]	0.01	[-0.007, 0.025]	0.01	[-0.008, 0.029]	0.01	[-0.011, 0.044]
Hangover								
# of alcohol products	0.03*	[0.002, 0.074]	0.03	[-0.001, 0.072]	0.02*	[0.003, 0.054]	0.01	[-0.004, 0.040]
# of cannabis products	0.02	[-0.011, 0.061]	0.01	[-0.004, 0.023]	0.03	[-0.010, 0.107]	0.01	[-0.006, 0.040]
Blackout								
# of alcohol products	0.07*	[0.017, 0.159]	0.09*	[0.035, 0.160]	0.06*	[0.020, 0.113]	0.03	[-0.008, 0.082]
# of cannabis products	0.03	[-0.022, 0.095]	0.01	[-0.009, 0.036]	0.01	[-0.009, 0.041]	0.01	[-0.016, 0.059]
Level-2 effects								
Number of consequences								
# of alcohol products	0.01	[-0.020, 0.044]	0.01	[-0.015, 0.037]	0.00	[-0.010, 0.024]	0.00	[-0.011, 0.024]
# of cannabis products	0.01	[-0.019, 0.048]	0.00	[-0.006, 0.014]	0.00	[-0.008, 0.010]	0.00	[-0.010, 0.027]
Nausea								
# of alcohol products	0.01	[-0.079, 0.112]	0.01	[-0.065, 0.091]	0.01	[-0.040, 0.060]	0.00	[-0.036, 0.062]
# of cannabis products	0.00	[-0.089, 0.095]	0.00	[-0.022, 0.025]	0.00	[-0.020, 0.020]	0.00	[-0.043, 0.049]
Hangover								
# of alcohol products	0.05	[-0.023, 0.189]	0.07	[-0.004, 0.168]	0.01	[-0.004, 0.026]	0.01	[-0.036, 0.106]
# of cannabis products	-0.02	[-0.132, 0.073]	-0.00	[-0.032, 0.022]	0.00	[-0.025, 0.021]	-0.00	[-0.065, 0.039]
Blackout								
# of alcohol products	0.01	[-0.138, 0.177]	0.02	[-0.110, 0.153]	0.01	[-0.061, 0.107]	0.00	[-0.064, 0.101]
# of cannabis products	0.04	[-0.083, 0.214]	0.00	[-0.025, 0.061]	0.00	[-0.034, 0.043]	0.01	[-0.046, 0.118]

Note. IE = indirect effect; 95% CI = 95% Bayesian credibility interval; Level-1 = within-person; Level-2 = between-person. Nausea, hangover, and blackout modeled as binary (yes/no). All models include the following covariates: age, sex, school (recruitment site), day of the week, other drug use, number of drinks, and number of cannabis uses. IEs are unstandardized.

\* Significant effects, such that credibility intervals do not overlap zero.

understanding of the neurocircuitry of addiction that posits the development into problematic use occurs over time (Koob & Volkow, 2010), rather than a day-to-day association as examined in studies employing daily diary and other experience-sampling methodologies.

Despite not finding total effects between using because it was offered and consequence outcomes, this reason for simultaneous use was endorsed on one third of SAM days. Thus, in addition to more deliberate motives (e.g., coping, effect-enhancement), future theoretical motivational models of simultaneous use could consider incorporating more opportunistic reasons for use, such as substance use offers and availability. Indeed, theories such as the Prototype Willingness Model (Gerrard et al., 2008; Gibbons et al., 2003) acknowledge that there are aspects of substance use that are not intentional and often reactions to the social environment. In sum, significantly more research is needed to (a) understand relations between motives and outcomes on SAM-use days and (b) advance our understanding of motivational models of substance use at the within-person level, which may contrast with our current theoretical understanding of motives and use developed from between-person mono-substance use research.

## Aim 2: Indirect Effects via Multiple Product Usage

Apart from the non-significant indirect effect of social motives on experiencing a hangover (and the null indirect effects found in coping

motives models), we robustly found that effect-enhancement, social, and offered motives exhibited significant within-person indirect effects on all consequence outcomes via the number of alcohol products used on that day, but not the number of cannabis products used. Examinations of path estimates revealed significant associations between these three specific motives and the number of cannabis products consumed, though, unlike for number of alcohol products, the number of cannabis products consumed on a given day was not significantly related to consequence outcomes tested in the present study. Coupled with Stevens et al. (2020a), who first supported the day-level risks associated with multiple product use, this evidence emphasizes the potential risks of using multiple alcohol products on a given SAM-use day.

“Avoiding mixing types of alcohol” has been recommended as a harm-reduction strategy related to manner of drinking (Martens et al., 2005, 2007); however, until now, the day-level deleterious effects of mixing alcohol products (in addition to mixing with cannabis) had yet to be examined. This evidence suggests that recommending that individuals limit the number of alcohol products used on a given SAM-use day, particularly for individuals engaging in simultaneous use for social reasons or for those who seek to achieve greater subjective effects when combining alcohol and cannabis, may reduce the likelihood of experiencing negative consequences—particularly hangover, nausea, and blackout. Though multiple cannabis product

usage did not emerge as a significant mediator in any model, future work is needed to determine the replicability of our findings once also considering additional consequences that are specific to cannabis use (e.g., lethargy/fatigue, feeling paranoid).

Interestingly, there was no significant within-person indirect effect of social motives on experiencing a hangover on a given day, whereas this indirect effect was significant for both effect-enhancement and offered motives. Other specific topographies of SAM-use, such as ordering, pre-gaming, taking shots, and rate of consumption, may better explain the relation between social motives and experiencing a hangover, and this could be explored in future research. Prior work has documented the influence of SAM-use on experiencing a hangover (Egan et al., 2019), and our findings extend this by showing that using for cross-fading reasons drives the consumption of multiple alcohol products on a given day, which, in turn, increases the occurrence of a hangover.

Using alcohol and cannabis together for cross-fading reasons suggests some intentionality behind consuming multiple substances and (potentially) multiple products of each substance, as demonstrated in the present study. These intentions are likely malleable and could be targeted in momentary interventions to encourage individuals to limit the number of alcohol products consumed during a given SAM-use occasion to reduce the likelihood of experiencing a hangover. Our findings also indicate that engaging in SAM use because alcohol or cannabis was offered influences the use of multiple alcohol products, which then leads to experiencing a hangover. Considering this motive is particularly opportunistic and likely difficult to target in the moment, individuals who report using for this reason should also be advised to limit the number of alcohol products consumed on a given SAM-use occasion to reduce the likelihood of experiencing a hangover (and other physiological consequences). Increasing their drink refusal self-efficacy may be particularly beneficial to individuals endorsing this reason for use (Choi et al., 2013).

Notably, liquor was the most frequently endorsed alcohol product in the present study, with liquor and beer and liquor and wine being the top two alcohol product combinations endorsed on SAM-use days in this sample. This is particularly concerning, considering the known risks of liquor consumption, compared to beer or wine consumption, with consuming liquor being more strongly related to negative consequences, alcohol dependence severity, treatment nonadherence, and severe medical consequences (e.g., Baltieri et al., 2009; Flensburg-Madsen et al., 2008; Greenfield & Rogers, 1999; Jensen et al., 2002; Klatsky et al., 2003). On the other hand, understanding that liquor is commonly used on SAM-use days, which may be driving the associations with the physiological consequences tested here, could be implemented into harm-reduction interventions for SAM use. Though more replication is needed, our preliminary findings suggest that liquor consumption should be avoided on SAM-use days to reduce the likelihood of experiencing a hangover, nausea, and a blackout. See Stevens et al. (2020) for further discussion of the clinical implications of understanding alcohol and cannabis product combinations.

Contrary to each other tested motive, coping motives did not exhibit significant indirect effects on consequences via multiple alcohol product use or via multiple cannabis product use. Path estimates show that coping motives were not related to consuming multiple alcohol products on a given SAM-use day but were to consuming multiple cannabis products, whereas the other three

motives were significantly related to both number of alcohol products and number of cannabis products. As stated above, relations between number of cannabis products and consequence outcomes were null in the present study, which explains why the indirect effects of coping motives via number of cannabis products did not emerge as significant. Though preliminary, our findings signal a relation between coping motives and using multiple cannabis products on a given co-use day. Together with Patrick et al. (2020), which showed a significant within-person relation between coping motives and cannabis consequences, this mediation model could be replicated in future work that includes consequences unique to cannabis use. Such research could determine whether consuming multiple cannabis products results in greater risks for consequences on days when co-using to cope or for other motives as well.

## Limitations and Future Directions

Despite the strengths of the present study, findings should be interpreted considering limitations. First, data were limited to college students and the majority self-identified as White, which limits the generalizability of our findings to other demographic groups. Second, the RDS did not capture data in real-time, and all reports required a small degree of retrospection. Third, motives were assessed via single items (due to time restrictions for administering multiple daily surveys), which poses limitations, as disparate relations can emerge when using single item indicators versus a comprehensive assessment of motives (Dvorak et al., 2014; Stevenson et al., 2019). Future work is needed to determine the replicability of our findings when using a more comprehensive assessment of co-use motives. Fourth, motives for alcohol use and for cannabis use may have differed on SAM-use days; however, our findings were unable to disentangle this possible discrepancy because of the way motives were assessed in the parent study. Future research could separately examine motives for alcohol, cannabis, and their simultaneous use to determine whether findings from the present study are replicable when motives are assessed in this manner.

Fifth, ordering of specific products (e.g., beer consumed before liquor) was not considered in the present study; thus, we are unable to assess myths related to product ordering on individual consequences (e.g., “beer before liquor, never been sicker”). Future studies may benefit from examining order of specific products when examining the relation between number of substance use products and related harms. Sixth, we observed small indirect effects in the present study; thus, findings should be considered preliminary, pending replication. However, our analyses were highly rigorous (disentangling within- from between-person effects) and conservatively adjusted for alcohol and cannabis consumption on a given day, along with other relevant covariates (e.g., other drug use). Seventh, consequence items included in the present study were largely drawn from the alcohol literature, consistent with prior research on SAM use (e.g., Brière et al., 2011; Egan et al., 2019; Linden-Carmichael et al., 2020). Nevertheless, this may have impacted study findings, particularly the null relations between using multiple cannabis products and consequences. Future research could replicate our aims and include consequences that are specific to cannabis-only use and/or SAM use to fully understand the

possible specificity between multiple alcohol products (vs. cannabis products) and consequences.

Notably, and as indicated above, many manners of SAM use exist that may also be related to motives and consequences, and these could be considered in future work (e.g., ordering of substances in co-use/simultaneous use occasion; Gunn et al., 2021). Though motives are considered malleable and proximal to the use event, the manner of SAM use during the event itself is also an important, though typically overlooked, intervention target that could be included in future just-in-time adaptive interventions (e.g., Nahum-Shani et al., 2014, 2018), particularly for SAM-use occasions marked by motives that are less predictable and inherently more difficult to target at the moment.

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