A daily study comparing alcohol-related positive and negative consequences for days with only alcohol use versus days with simultaneous alcohol and marijuana use in a community sample of young adults

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Abstract

Background—Alcohol and marijuana are psychoactive substances commonly used by young adults and are independently associated with numerous acute and long-term consequences. Many young adults engage in simultaneous alcohol and marijuana (SAM) use to cross-fade (i.e., to enhance the effects of intoxication), although the extent to which alcohol use and alcohol-related consequences increase on SAM occasions compared to alcohol-only occasions is unclear. This study examines daily data among a sample of SAM users comparing SAM days to other days when young adults only used alcohol.

Methods—A sample of 409 young adults (age 18–25; M age = 21.6, SD= 2.2; 50.9% women) who reported SAM use in the past month completed two bursts of 14 days of daily surveys (28 days in total) assessing alcohol use, alcohol-related consequences, and SAM use.

Results—Multilevel models based on alcohol-only and SAM days (n=3,016 days; 391 individuals) indicated young adults drank more alcohol on SAM days compared to alcohol-only days (with no marijuana use). Similarly, days with SAM use were associated with more alcohol-related positive and negative consequences. The daily association between SAM use and positive consequences was statistically significant, after accounting for the amount of alcohol consumed; in contrast, the association between SAM use and negative consequences was diminished and nonsignificant.

Conclusions—Among young adult SAM users, days with SAM use was associated with more alcohol use and positive consequences compared to days they only drank alcohol. Further examination of the motivational context for engaging in SAM use, as well as potential

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physiological interactions between alcohol and marijuana use on alcohol's effects, is warranted. Alcohol interventions might benefit from addressing increased alcohol use and alcohol-related consequences as risks associated with SAM use.

Keywords

simultaneous alcohol and marijuana use; consequences; young adult; daily

Recreational marijuana use has been legalized for adults in the United States who are 21 years or older in eleven states and the District of Columbia, with other states currently debating similar legislation. There have been policy and epidemiological debates as to whether such changes in marijuana policy may have implications for alcohol use on the population and individual levels (Pacula & Sevigny, 2014). For example, it is possible that less restrictive policies may lead to increases in marijuana use and alcohol use at both the individual or population level, consistent with complementary effects associated with alcohol and marijuana use whereby individuals consistently increase their use of both substances. Alternatively, increases in marijuana use may lead to decreases in overall prevalence of alcohol use if there are substitution effects (i.e., decrease in alcohol as individuals consistently choose to use marijuana instead).

While published researched has focused on population level impacts, it is also important to examine what may be happening at the occasion or acute level among individuals who use both alcohol and marijuana, especially because occasion-level effects can vary day to day without resulting in a more stable complementary or substitution effects. That is, when individuals use alcohol, do they tend to drink more or less, and are their alcohol-related risks enhanced or decreased when marijuana is also used at the same time? The present study used an intensive measurement-burst design with a community sample of young adult simultaneous alcohol and marijuana (SAM) users to understand the acute impacts of SAM use at the occasion level and whether the use of marijuana with alcohol at the same time was associated with complementary or substitution effects with alcohol on a given occasion.

SAM Use and Consequences among Young Adults

Alcohol use is common among young adults, with 82% using alcohol in the past year and 34% engaging in heavy episodic drinking in the past two weeks (Schulenberg et al., 2018), and alcohol use leads to well-documented risks to individuals and communities (Hingson, Heeran, Winter, & Wechsler, 2005; White & Hingson, 2013; Yi et al., 2004). Marijuana use is also common among young adults, with 38% using in the past year (Schulenberg et al., 2018), and prevalence potentially increasing (e.g., White et al., 2019), especially in states like Washington where recreational marijuana is legal for adults (21+). Most young adults who use marijuana also use alcohol (Patrick, Terry-McElrath, Lee & Schulenberg, 2019), and recent research indicates simultaneous use of alcohol and marijuana is associated with greater alcohol use compared to drinking occasions without using marijuana among veterans (Metrik et al, 2018). SAM users have been found to be higher on risk factors such as perceived norms of peer SAM use and sensation seeking (e.g., Linden-Carmichael, Stamates, & Lau-Barraco, 2019; White et al., 2019).

Some young adults report engaging in SAM use in order to get "cross-faded," whereby young adults increase their levels of intoxication via simultaneous alcohol and marijuana use (Patrick & Lee, 2018). Simultaneous use of both alcohol and marijuana use is prevalent among adolescents and young adults (Briere, Fallu, Descheneaxu, & Janosz, 2011; Patrick et al., 2018; Patrick, Terry-McElrath, Lee, & Schulenberg, 2019; Subbaraman & Kerr, 2015). Findings suggest that between 15–23% of adolescents and young adults engaged in SAM use within the past year (Subbaraman & Kerr, 2015; Terry-McElrath, O'Malley, & Johnston, 2013). SAM use has been associated with several negative consequences, including legal, academic, interpersonal, physical, and mental health problems (Briere et al., 2011; Midanik, Tam, & Weisner, 2007; Pape, Rossow, & Storvoll, 2009). Using cross-sectional data to compare typical alcohol-only occasions with typical SAM occasions, SAM use occasions were found to be associated with greater subjective negative physiological and cognitive effects (i.e., feeling clumsy, confused, dizzy, difficulty concentrating) (Lee, Cadigan, & Patrick, 2017). SAM use, when compared to alcohol-only use, has been associated with greater harm related to social relationships and physical health, higher incidence of motor vehicle collisions, higher rates of drunk driving, and higher rates of using alcohol and marijuana (e.g., Brière et al., 2011; Terry-McElrath, O'Malley, & Johnston, 2014; Sewell, Poling, & Sofuoglu, 2009; Subbaraman & Kerr, 2015); however, none of these studies have examined whether more alcohol-related consequences are experienced on specific SAM use occasions, using repeated measures over time.

Using six retrospective weekend surveys with college students assessing alcohol and marijuana use on Thursdays, Fridays, and Saturdays, Mallett and colleagues (2019) compared the number of consequences reported on different types of drinking days including: heavier alcohol with same day marijuana use; lighter alcohol combined with same day marijuana use; heavier alcohol only; lighter alcohol only; and marijuana only use and found that heavy drinking occasions with or without same day marijuana use did not differ in the number of negative consequences reported. Findings suggested that a greater number of negative consequences were reported on heavy drinking days (with or without same day marijuana use) compared to lighter drinking days (with or without marijuana) or marijuana-only days. However, prior work (Mallett et al., 2017) has found that students who combined alcohol with marijuana and/or other substances had increased negative consequences compared to students who only used alcohol. With an adolescent sample, Lipperman-Kreda and colleagues (2017) found occasions with SAM use were associated with a 110% increase in number of negative behavioral consequences (e.g., driving after drinking, getting into a verbal argument or physical fight) compared to occasions with no substance use, and this was largely associated with increased alcohol consumed on those occasions.

Although SAM use may be associated with greater alcohol use, it is unclear the extent to which SAM use on specific occasions is associated with increases in a broader array of consequences that include both positive and negative alcohol-related consequences and if so, whether these effects are partially accounted for by greater alcohol use (due to the tendency to drink more on SAM days). From a motivational perspective, it is important to understand the perceived positive effects young adults report, in order to understand how consequences may act as reinforcers for heavy drinking. Several studies have documented perceived positive effects from alcohol using either cross-sectional data or using daily longitudinal

data (Park, 2004; Patrick & Maggs, 2011; Patrick et al., 2016) and typically find positive consequences are reported significantly more frequently than negative consequences (Park, 2004; Park & Grant, 2005; Park & Levenson, 2002; Patrick& Maggs, 2008). Understanding the potential effects of SAM use on perceived positive and negative consequences is important for understanding individuals' potential for continued engagement and/or escalations in high-risk behaviors, like SAM use.

Present Study

Previous research has not examined whether SAM use is associated with increases in total alcohol consumed (e.g., complementary effects, where using marijuana at the same time as alcohol increases amount consumed) or decreases in total alcohol consumed (e.g., substitution effects, where individuals drink less when they use marijuana) at the occasion level in a community sample of young adults who use alcohol and marijuana. Alcohol-related consequences associated with SAM use may result from additive and/or interactive (synergistic) effects that occur as a result of the pharmacological combination of substances, and therefore increase overall risk and harm when compared to use of either alcohol or marijuana alone (Briere et al., 2011). Further, beyond looking at risk, research also needs to examine the reinforcing mechanisms of SAM use, such as perceived positive effects from SAM use. By examining both positive and negative effects at the daily level, as well as specifically assessing whether alcohol and marijuana were used simultaneously, research can compare acute effects on days with SAM use compared to days with other alcohol use, and this enhanced understanding has important implications for targeted interventions among SAM users.

The purpose of the present study was to use an intensive measurement burst, daily design to collect multiple daily assessments of alcohol and SAM use among the same individuals over time. We focus on alcohol-related positive and negative consequences (rather than more general consequences resulting from any substance use), because we were interested in isolating the impacts of using marijuana at the same time as alcohol on the experience of alcohol-related consequences. With a total of up to 28 days of reporting across two 14-day bursts, we examined: (1) whether SAM use days were associated with greater alcohol use and also with more positive and negative alcohol-related consequences, compared to alcohol-only days (with no marijuana use); and (2) whether the effect of SAM use on positive and negative alcohol-related consequences was accounted for by increased alcohol use. We hypothesized that days with SAM use would be associated with greater alcohol use compared to alcohol-only days and that SAM use would be associated with greater reports of perceived positive and negative alcohol-related effects or consequences. Based on findings from prior studies (e.g., Lipperman-Kreda et al., 2017; Mallett et al., 2019), we further hypothesized that greater alcohol use on SAM occasions may account for the effects of SAM use on alcohol-related consequences.

Method

Participants

Participants were 409 young adults participating in a longitudinal study on daily health behaviors and experiences. To be eligible, participants were required to be between 18–25 years of age at screening; report engaging in simultaneous alcohol and marijuana use at least once in the prior month; report drinking alcohol at least three times in the past month; live within 60 miles of the study office (located in Seattle, WA); be willing to complete online daily surveys during allotted time frames; be willing to receive text messages from the project; and come to the study office for consent, identity/age verification, and completion of a baseline survey. Longitudinal study procedures included completing assessments twice daily (once in the morning and once in the late afternoon) for six 14-day bursts across two years. Present analyses use morning survey data from the first 2 bursts collected in 2018 and 2019 as well as demographic data from baseline.

The sample is 58.3% White, 17.4% Asian or Pacific Islander American, 13.8% Multiple Races, 5.4% African American, 4.2% other, and 1.5% Native American. In addition, 16.0% reported being Hispanic/Latino. Average age at baseline was 21.61 years (SD=2.17), and 50.9% reported birth sex as female. With respect to gender, 48.2% identified as female, 48.4% identified as male, 3.4% responded "other," and two individuals declined to answer. Regarding sexual orientation, 70.1% identified as heterosexual. At baseline, 62.6% were enrolled in post-secondary education (6.6% in a two-year college, 48.9% in a four-year college, and 7.2% in a graduate or professional program). Over half the sample (66.0%) were employed at baseline, 40.8% part-time and 25.2% full-time.

Procedures

The University's Institutional Review Board approved all procedures. Recruitment occurred in the Seattle metropolitan area in Washington State, where non-medical marijuana use is legal for adults 21 years and older. A multi-method approach for recruitment included online, print, and social media advertisements; outreach at community colleges and local events targeting young adults; flyers posted in local community settings; outreach to community agencies that work with or employ young adults; and friend referral. Individuals were directed to the study website or to call the study office for more information and complete a brief confidential online survey to determine eligibility. Eligible individuals were asked to attend an in-person session in the study's local office within 30 days.

During the 1½ to 2 hour in-person session, each participant verified identity and age with a driver's license or other photo identification, completed informed consent procedures, and received a 30-minute training session about procedures for completing the daily surveys. The training consisted of practical information, such as time frames for survey completion, assessment length, and payment schedule, as well as details on the more complex survey questions and discussion about the definition of SAM use. A project brochure, which outlined much of the information described in the training session, was given to all participants. Finally, participants completed a 60-minute online baseline survey in the lab. The baseline survey included questions about demographic information, alcohol and

marijuana use, and a variety of psychosocial and behavioral characteristics; participants received a $40 Amazon gift card upon completion.

The following day, participants started their first 14-day burst of twice-daily online surveys (i.e., morning and afternoon assessments; only morning assessments described here). The morning assessment was completed between the default hours of 9am to 12pm. All survey windows were three hours. Four months later, participants started a second 14-day burst of online surveys. Data from Bursts 1 and 2 used in the current analyses were collected during the morning assessments, which included items about the previous day's substance use and alcohol-related consequences. Participants were sent email and text invitations with links to the survey at the opening of each survey window, as well as a reminder text(s) to complete the survey. The daily surveys took 5 to 10 minutes to complete. At the end of each 14-day burst, participants were emailed Amazon gift card codes as compensation. Participants earned $2.50 for each daily survey completed and a $10 bonus for each burst if at least 25 of the 28 surveys were completed. Participants who completed all daily surveys over the 14 days in a given burst earned $80 in Amazon gift cards.

In Burst 1, participants completed over 88% of the morning assessments, with an average of 12.38 (SD=2.21) of the 14 surveys completed per participant. At least 10 morning surveys in Burst 1 were completed by 91.0% of the sample. In Burst 2, participants completed over 79.9% of the morning assessments (M=11.19, SD=3.89) and 79.2% completed at least 10 morning surveys. The total number of morning surveys used in the current study is 9,641.

Measures

Daily substance use pattern—In the morning surveys, participants were asked to report whether, during the prior day, they used alcohol and marijuana; "Did you drink any alcohol yesterday?" (0=no, 1=yes) and "Did you use any marijuana yesterday?" (0=no, 1=yes). To assess SAM use, if they reported using alcohol and marijuana, they were asked, "Yesterday, did you use alcohol and marijuana at the same time – that is, so that their effects overlapped?" (0=no, 1=yes). A code of "0" was given on days that an individual did not report using either alcohol or marijuana (and were therefore not asked the SAM use question). The pattern of use for each day was categorized as (1) no alcohol or marijuana use, (2) alcohol use but no marijuana use, (3) marijuana use but no alcohol use, (4) alcohol and marijuana use but no SAM use, or (5) SAM use. Participants were provided with the NIAAA definition and figure of a standard drink: 12 fl. oz. of regular beer, 8–9 fl. oz. of malt liquor, 5 fl. oz. of table wine, and 1.5 fl. oz. shot of distilled spirits.

Amount and consequences of alcohol use—Amount of alcohol use was assessed by asking participants who drank alcohol during the prior day, "How many total drinks did you have yesterday?" Participants responded using a drop down menu from "one drink" (coded 1) to "25 or more drinks" (coded 25).

Participants were asked if they had experienced 21 possible alcohol-related consequences (0=no, 1=yes). A total of thirteen positive (n=6 positive consequences; e.g., "Felt relaxed" and "Was in a better mood") and negative alcohol-related consequences (n=7 negative consequences; e.g., "Had a hangover" and "Felt nauseated or vomited") came directly from

the Daily Alcohol-related Consequences and Evaluations for Young Adults measure (Lee et al., 2017). To obtain a broader assessment of acute negative alcohol consequences that participants may experience, eight additional negative alcohol-related consequences were assessed: "Got into a serious fight,"", "Passed out or fainted suddenly,"", "Had a blackout,"", "Damaged property on purpose,"", "Felt clumsy,"", "Had difficulty concentrating,"", "Felt confused,"", and "Felt dizzy" (Lee, Cadigan, & Patrick, 2017; Schukit & Gold, 1988; White & Labouvie, 1989). Sum scores were created for total numbers of positive (out of 6) and negative (out of 15) consequences experienced.

Covariates—In models predicting amount and alcohol-related consequences of substance use, we included person-level covariates for age, biological sex, and whether participants were attending a four-year college. These variables were based on self-reports from the baseline survey. We also included within-person covariates for whether the reference day (i.e., day substance use occurred) was a Thursday, Friday, or Saturday ("weekend" days for young adults) versus some other day of the week; whether the day was in the second Burst 2 versus Burst 1; and which day (1–7) the reference day was within the given burst.

Analysis

Prior to testing the main aims, the first stage of analyses involved examining descriptive information on daily substance use patterns as well as measures of alcohol use and alcohol-related consequences. To test Aims 1 and 2, regarding whether SAM days were associated with greater alcohol use and alcohol consequences (Aim 1), and whether associations between SAM days and consequences were still present after controlling for number of drinks (Aim 2), a series of multilevel models were estimated with HLM 7.0 (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011). For models testing Aims 1 and 2, only days with alcohol use (but not marijuana use) and days with SAM use were analyzed; we excluded days with alcohol and marijuana use but no SAM use so that comparisons could be made between SAM use and alcohol use only. These models predicted number of drinks and number of positive or negative alcohol consequences on a given day, with predictors at both the person level and the daily within-person level. For all of these models, within-person predictors were whether or not the reference day involved SAM use whether or not the reference day was the weekend, the burst number, and the day within the burst. At the person level, predictors were proportion of days that were SAM use days across the two bursts, age, biological sex, and four-year college status. For models predicting positive and negative alcohol-related consequences, a first model was run with the above predictors (Aim 1). Then a second model was run that adjusted for amount of alcohol consumed on the given day (Aim 2) by including a person-level control for the average number of drinks consumed on drinking days and a within-person-level control for number of drinks consumed on the reference day. In all of the multilevel models, person-level predictors were grand-mean centered and within-person predictors of SAM use and amount of alcohol use were centered within individuals. All outcomes examined in the multilevel models were counts, and Poisson models with overdispersion were used. Rate Ratios (RRs; also sometimes referred to as count ratios or incident rate ratios) are reported, which describe the proportional change in the count associated with a 1-unit increase in the predictor of interest (e.g., SAM

compared to alcohol-only; Atkins & Gallop, 2007). Population-average estimates with robust standard errors were used for all models.

The number of days for each individual included in the multilevel analyses varied from 1 to 24. The modeling approach used makes the assumption that data are missing at random after taking into account all model covariates. Given the selection criteria for determining the subset of days used to test the Aims, the inferences that can be made are to days that involve alcohol-only use (but not marijuana use) or days that involve SAM use among a population of individuals who have at least one day that falls into one of those two substance use categories.

Results

Descriptive Statistics

Data were collected on a total of 9,641 days across 409 participants. Descriptively across all sampled days, neither alcohol nor marijuana use was reported on 3,743 (38.8%) days, alcohol only on 1,966 (20.4%), marijuana only on 2,235 (23.2%), alcohol and marijuana but not SAM on 647 (6.7%), and SAM on 1,050 (10.9%). Further, any alcohol use (regardless of marijuana status) was reported on 38.0% of days, and SAM use was reported on 28.7% of days with any alcohol. At least one day of alcohol use was reported by 398 individuals, resulting in the exclusion of 11 because they did not report alcohol use across any sampled days. At least one day of SAM use was reported by 282 individuals. Finally, eight individuals were excluded because they only reported alcohol use on days when they also used marijuana but did not engage in SAM use. The final analytic sample included a total of 3,016 days across 391 participants. On drinking days included in the multilevel analysis, respondents reported consuming a mean of 3.89 (SD=2.94) drinks. A total of 91.4% of drinking days involved at least 1 positive consequence, and 33.2% involved at least 1 negative consequence. The mean number of positive alcohol-related consequences was 3.30 (SD=1.89); the mean number of negative alcohol-related consequences was 0.77 (SD=1.49).

Alcohol Use on SAM days vs. Alcohol-Only Days

Table 1 presents estimates from models testing whether alcohol use is greater on SAM days. Between-person (Level 2) results showed that participants who had more SAM use days over the data collection period drank more, on average, on drinking days. Males and younger participants also drank more across days, but there were no significant differences based on college status.

Within-person (Level 1) results indicated that SAM use was positively associated with number of drinks consumed on a given day. Days with SAM use were associated with more drinks consumed compared to alcohol-only use days. SAM use was associated with consuming 14% more drinks than on alcohol-only use days without SAM use. Weekend days were associated with 23% more drinks than weekdays, but there were no significant effects of burst or day within burst.

Alcohol-related Consequences on SAM vs. Alcohol-only Days (Aim 1)

Estimates from models predicting positive and negative alcohol-related consequences are also shown in Table 1 (see columns in Table 1 labeled "Positive Consequences (Model 1)" and "Negative Consequences (Model 1)" that do not control for alcohol use that day). Between-person results indicated the proportion of SAM use days was not significantly associated with average number of positive or negative alcohol-related consequences experienced. There were no significant effects of sex, age, or college status on positive alcohol-related consequences. For negative alcohol-related consequences, males and older participants reported fewer negative consequences, but there were no differences based on college status.

Within-person results indicated SAM use on a given day was positively associated with more positive and more negative alcohol-related consequences. Participants reported 15% more positive alcohol-related consequences and 28% more negative alcohol-related consequences on SAM days than on other alcohol-only days. More positive and negative alcohol-related consequences were reported on weekends than weekdays, and the number of positive (but not negative) consequences experienced decreased over time (by burst and day in burst).

SAM Use Effects Accounted for by Number of Drinks (Aim 2)

To test whether the effects of SAM use were explained by the increased number of drinks on SAM days, number of drinks was added as both a between-person and a within-person predictor (see columns in Table 1 labeled "Positive Consequences (Model 2)" and "Negative Consequences (Model 2)" that control for alcohol use that day). When controlling for number of drinks, all substantive interpretation of the other between- and within-person predictors remained the same. At the between-person level, average number of drinks on drinking days was associated with more positive and more negative alcohol-related consequences. At the within-person level, number of drinks on a given day was also associated with more positive and more negative alcohol-related consequences.

These within-person effects of SAM use on a given day on both positive and negative alcohol-related consequences were diminished when accounting for number of drinks consumed. For positive alcohol consequences, the RR was reduced from 1.15 to 1.10; for negative alcohol consequences, the RR was reduced from 1.28 to 1.08. In the latter case, the unique association between SAM use and negative consequences was no longer statistically significant. These results suggest that number of drinks consumed on SAM days partially accounted for the effects of SAM on negative alcohol-related consequences.

Discussion

There has been increased public health interest in the extent to which using marijuana simultaneously with alcohol may impact both alcohol consumption and alcohol-related consequences from a broader population level policy perspective as well as in terms of individual-level risk. The ability to examine behavior within the same individual across days can isolate days when individuals used alcohol and marijuana simultaneously and compare

use and alcohol consequences on those days to alcohol-only use days, while controlling for how often they generally engaged in SAM use. Overall, results from this study overwhelmingly indicated complementary effects of marijuana on alcohol use. That is, on days during which young adults used alcohol and marijuana simultaneously, they consumed more drinks and experienced more alcohol-related consequences compared to alcohol-only days. Findings are consistent with other research examining patterns of alcohol use on alcohol and marijuana co-use days compared with single substance use days. For example, Metrik et al., (2018) found that heavy drinking was more likely to occur on days when marijuana use was also reported, using timeline follow-back approaches among a sample of veterans.

Previous studies indicate that some young adults consciously use alcohol and marijuana simultaneously to get cross-faded effects, meaning to enhance the intoxicated effects (Patrick & Lee, 2018). Further, specific reasons young adults engage in SAM use have been found to be related to enhancing positive effects, such as to attain better or enhanced effects when alcohol and marijuana are combined (Patrick, Fairlie, & Lee, 2018). If young adults' goals for SAM use are to increase their positive effects of substance use or to be cross-faded, it makes sense that SAM use would also be associated with greater alcohol use compared to alcohol-only days. Future research could further examine the motivational context of SAM use on given occasions and the extent to which the likelihood of SAM use or the intensity of alcohol use on SAM days is associated with particular motives for increased intoxication or enhancement or other motives.

Individuals who engage in more frequent SAM use across the study tended to drink more across the study. It appears, however, that alcohol-related consequences are more associated with whether one is engaging on SAM use on any given day (regardless of whether we account for how much they drink or not for positive consequences), compared to just being a more frequent SAM user. Findings indicated that days with SAM use were associated with more positive alcohol-related consequences (with and without controlling for amount of alcohol consumed) and negative alcohol-related consequences (only without controlling for amount of alcohol consumed) compared to alcohol-only use days. These findings differ from Mallett and colleagues (2019), who found college students with heavy alcohol use on SAM use days was not associated with more consequences when compared to heavy drinking only days. There are several possibilities for these mixed findings, including key demographic and methodological differences between studies. For example, compared to the relatively homogenous college student population (Mallett et al., 2019), participants in the present study were quite diverse with regard to college-status, gender, racial background, and sexual orientation status, Daily data in the present study was also collected every day, compared to weekend-only days as reported by Mallett et al. (2019).

Extending prior research, the daily associations between SAM use and alcohol-related consequences were found to be partially explained by alcohol use. That is, the increase in the number of positive and negative alcohol-related consequences on SAM days was in part due to the increased alcohol consumption on SAM days. However, effects of SAM use on number of negative consequences did not remain after accounting for the increased use of alcohol, suggesting that the link between SAM days and negative consequences is largely

due to increased alcohol use. Recent work also documents an expectancy effect for alcohol use (i.e., days with greater expectations about more subjective positive effects of alcohol were associated with greater likelihood of reporting the same effects even after controlling for alcohol use, Lee et al., 2019). Although the present study does not assess alcohol or SAM expectancies, it does provide important evidence that SAM use is associated with greater reports of positive alcohol-related consequences. Future research could examine to what extent this is also an expectancy effect (either of alcohol or SAM use).

Because SAM use is associated with both heavier alcohol use on that occasion and alcohol use is associated with more alcohol-related negative consequences, alcohol interventions developed for young adults would benefit from addressing risks of SAM use. This information could be incorporated into existing motivational and skill-based interventions for young adult alcohol and marijuana users, implemented individually, in groups, or via web- or app-based technology. As SAM use may be motivated to increase the perceived positive effects associated with being cross-faded, a motivational approach balancing the perceived positive alcohol consequences against the experienced harmful consequences and discussing ways to minimize harm may be beneficial. The current study used indices of alcohol-related positive and negative consequences. A question that could be explored in future research is whether there are particular consequences, or clusters of consequences, that have strong associations with SAM use.

The findings should be viewed in light of certain limitations. All measures of substance use and consequences were self-reported, and the study lacked a measure of participants' sensitivity to social desirability. The sample included young adults (i.e., at screening having reported drinking at least 3 or more times in the past month and engaging in SAM use at least once in the past month) from an urban area in Washington State where recreational marijuana use was legalized for adults 21 and older in 2012 and retail stores opened in 2014. Results may not generalize to other areas, particularly those in states with different marijuana policies, or to young adults with lower-risk substance use patterns. Additionally, the community sample, recruited largely through social media and online ads, likely differs from the general population of young adults in the US in important ways. For example, 30% of the sample did not identify their sexual orientation as heterosexual. Future research should explore whether associations between SAM use and substance use consequences differ by sexual minority status. While the present manuscript only examined effect of SAM use on alcohol-related consequences, future EMA studies could examine associations between simultaneous use and days of co-use of alcohol with other drugs (e.g., nicotine, prescription stimulants, cocaine, Mallett et al., 2017; Roche et al., 2019) and both positive and negative alcohol and substance-related consequences.

Although findings show SAM days are associated with greater alcohol use, it is also possible that heavy drinking is itself a risk-factor for SAM use. We encourage future work to examine the directionality of this association. Despite these limitations, the current findings elucidate how SAM use on certain days is associated with increased alcohol use and alcohol-related consequences compared to days when alcohol, but not marijuana, is used.

Acknowledgments

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Table 1.

Estimates of fixed effects from multilevel models predicting amount and consequences of SAM use on alcohol use days (n=391 persons, 3,016 drinking days).

Predictor	Number of drinks		Positive consequences (Model 1)		Positive consequences (Model 2)		Negative consequences (Model 1)		Negative consequences (Model 2)	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Level 2, Between-person										
Intercept	2.63***	(2.22,3.12)	3.46***	(3.06,3.91)	3.59***	(3.19,4.03)	1.05	(0.72,1.51)	1.10	(0.76,1.59)
Proportion of days that were SAM days	1.55**	(1.13,2.13)	1.17	(0.90,1.51)	1.04	(0.79,1.39)	1.36	(0.69,2.67)	1.18	(0.57,2.45)
Male	1.20***	(1.10,1.31)	0.99	(0.92,1.06)	0.97	(0.91,1.04)	0.76**	(0.63,0.91)	0.68***	(0.56,0.82)
Age	0.94***	(0.92,0.97)	0.98	(0.96,1.00)	0.98	(0.96,1.00)	0.89***	(0.84,0.95)	0.89***	(0.84,0.95)
In 4-year college	1.02	(0.91,1.16)	1.02	(0.94,1.12)	1.03	(0.94,1.12)	1.10	(0.86,1.41)	1.09	(0.85,1.40)
Avg. # of drinks on drinking days					1.03**	(1.01,1.06)			1.05	(0.97,1.14)
Level 1, Within-person										
SAM days (versus alcohol-only days)	1.14**	(1.05,1.24)	1.15***	(1.08,1.21)	1.10***	(1.04,1.15)	1.28**	(1.07,1.54)	1.08	(0.94,1.24)
# of drinks on reference day					1.08***	(1.07,1.10)			1.30***	(1.27,1.33)
Weekend	1.23***	(1.16,1.29)	1.11***	(1.07,1.15)	1.04*	(1.00,1.08)	1.33***	(1.17,1.50)	1.16**	(1.04,1.29)
Burst 2	0.95	(0.90,1.00)	0.95*	(0.92,0.99)	0.97	(0.93,1.00)	0.95	(0.84,1.07)	0.97	(0.87,1.09)
Day number within burst	1.00	(0.995,1.01)	0.99***	(0.99,0.995)	0.99***	(0.985,0.994)	1.00	(0.98,1.01)	1.00	(0.99,1.01)

Note. Model 1 does not control for alcohol use, while Model 2 does control for alcohol use (number of drinks consumed that day). *RR*=rate ratio.

*
p < .05.

**
p < .01.

***
p < .001.