

Daily Relations Among Alcohol and Cannabis Co-Use, Simultaneous Use, and Negative Consequences: A Day-Level Latent Profile Analysis

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ABSTRACT

Objective: Concurrent and simultaneous cannabis and alcohol co-use confers risk for daily negative alcohol consequences. However, studies often treat co-use as a dichotomy, precluding examination of higher- and lower-risk co-use days. Additionally, little is known about specific alcohol consequences associated with daily co-use. Therefore, the current study 1) differentiated days based upon alcohol consumption, co-use, and simultaneous use, and 2) tested whether certain day-level use patterns conferred risk for daily alcohol consequences. **Methods:** College student co-users (N=489) completed an online Timeline Followback, reporting daily alcohol consumption, negative alcohol consequences, concurrent cannabis and alcohol co-use, and simultaneous co-use (SAM) on drinking days over the past month. Day-Level Latent Profile Analysis differentiated days based upon drinking quantity, co-use, and simultaneous use, and tested whether patterns of use conferred risk for overall and specific negative alcohol consequences. **Results:** Four day-level profiles emerged, including moderate consumption of alcohol-only days (57.5%), moderate consumption SAM use days (29.1%), higher consumption alcohol-only days (7.4%), and higher consumption SAM use days (6%). Higher consumption SAM use days were associated with more negative alcohol consequences than all other days; however, higher consumption SAM use days differed from higher consumption alcohol-only days in acute dependence symptoms. Higher consumption alcohol-only days were associated with more negative alcohol consequences than moderate consumption SAM days, particularly those that were action-oriented (i.e., dependence symptoms, blackout drinking, impaired control, risky behavior, social/interpersonal consequences). **Conclusions:** Findings suggest that there are in fact lower-risk co-use days, and that links with unique negative alcohol consequences depend on levels of alcohol consumption and co-use.

Key words: = alcohol; cannabis; co-use; negative alcohol consequences; timeline followback

Cannabis and alcohol are the most frequently used substances on college campuses (Linden-Carmichael & Lanza, 2018; Schulenberg et al., 2020; Slutske, 2005). Cannabis and alcohol are independently associated with a variety of negative alcohol consequences and harms (e.g., Meier et al., 2012; Volkow et al., 2014; Waddell, 2022; Waddell et al., 2022a), however risk is increased when cannabis and alcohol are used

together (Yurasek et al., 2017; Gunn et al., 2022; Lee et al., 2022). At the person-level, co-users (i.e., individuals who report using alcohol and cannabis) report heavier cannabis and alcohol consumption and more negative alcohol consequences/harms compared to single substance users (Brière et al., 2011; Linden-Carmichael et al., 2019; Midanik et al., 2007; Waddell, 2021; Waddell, Blake, & Chassin, 2021).

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In addition, co-use (vs. single substance use) days are associated with heavier day-level consumption and negative alcohol consequences/harms experienced (e.g., Lee et al., 2020; Linden-Carmichael et al., 2020; Mallet et al., 2017; 2019; Metrik et al., 2018; Waddell et al., 2021b).

Although relations among co-use and negative daily outcomes are well documented, most studies consider co-use a dichotomy (i.e., co-use vs. single substance use). However, it is possible that there are both low-risk and high-risk co-use days that get grouped together when testing day-level risk. In support of this possibility, Mallet et al. (2019) used daily diary data to group days into four theoretical categories indicative of non-binge alcohol-only, non-binge co-use, binge alcohol-only, and binge co-use days in college students. Mallet et al. (2019) found that binge co-use days were associated with more day-level negative alcohol consequences than non-binge alcohol-only and non-binge co-use days, but binge co-use days did not differ from binge alcohol-only days in terms of alcohol consequences. In addition, Mallet et al. (2019) found that non-binge alcohol-only days were associated with fewer alcohol consequences than binge alcohol-only and binge co-use days but did not differ from non-binge co-use days.

Although informative, the results of this study leave remaining questions. First, lower-risk co-use was not used as a reference group, and thus Mallet et al. (2019) was not able to test whether lower-risk co-use differed from higher-risk alcohol-only use in terms of negative alcohol consequences. Person-level studies suggest that level of alcohol consumption is a stronger predictor of negative alcohol consequences than co-use (e.g., Waddell, 2022b), but day-level studies have yet to examine whether co-use days coupled with lower drinking quantity differ from higher consumption alcohol-only days. Second, Mallet et al. (2019) assessed total alcohol consequences, social alcohol consequences, and blackouts, but there are a variety of other unique alcohol consequences that may be related to co-use patterns at the day-level in college students. Thus, it is important to understand associations between day-level co-use and specific alcohol consequences in college students, such as alcohol consequences affecting a student's academics/occupation, as well as higher severity (e.g., day-level dependence symptoms) vs. lower severity alcohol consequences

(e.g., day-level lack of self-care). Third, the Mallet et al. (2019) study did not specify whether alcohol and cannabis were used simultaneously (SAM), which is defined as using alcohol and cannabis so that their effects overlap (Gunn, Aston, & Metrik, 2022). Since prior research suggests that simultaneous use confers risk above and beyond non-simultaneous co-use (Jackson et al., 2020), it is important to disentangle relations between co-use (i.e., using both substances but not overlapping) and SAM use (i.e., using both substances so that their effects overlap). Finally, Mallet et al. (2019) created theoretical categories of alcohol-only and co-use at the day-level rather than examining data-driven profiles of day-level use. Importantly, only 1.8% of days were categorized as non-binge co-use days, suggesting that there may be other patterns that emerge using a data-driven strategy.

Therefore, the current study sought to test whether days characterized by cannabis and alcohol co-use, simultaneous use, and levels of alcohol consumption were differentially associated with total and specific day-level negative alcohol consequences. The current study used Day-Level Latent Profile Analysis (LPA), a modern mixture modeling technique that generates latent profiles using daily diary data while correcting for person-level clustering (i.e., Linden-Carmichael et al., 2022). It was hypothesized that there would be at least four profiles of day-level use behavior, indicative of lower-risk alcohol-only use, higher-risk alcohol-only use, lower-risk co-use, and higher-risk simultaneous use (SAM). It was further hypothesized that higher-risk SAM use would be associated with the highest level of negative alcohol consequences, and that higher-risk alcohol-only use would be associated with more negative alcohol consequences compared to lower-risk profiles, even if co-use was present. Analyses related to unique negative alcohol consequences were considered exploratory.

METHODS

Participants

College students who reported past-month simultaneous cannabis and alcohol use (N=489) were recruited from a large southwestern university as part of a study focused on co-use expectancies (Waddell et al., 2022). A total of N=657 students were recruited, however the

current study was limited to participants who completed an online, modified Timeline Followback (TLFB) interview and reported at least one co-use day via the TLFB, making the analytic sample $N=489$. Past 30-day co-use was selected as inclusion criteria so that each participant would have at least one co-use day to analyze, in line with other TLFB studies (e.g., Gunn et al., 2019; Metrik et al., 2018; Waddell et al., 2021). Participants were 68.7% female, had a mean age of 19.89 ($SD=1.90$), and identified as 74.4% White/Caucasian, 4.7% Black/African American, 8.8% Asian, .7% Pacific Islander/Hawaiian, 1.6% Native American/Indigenous, and 9.9% other; 25.1% identified as Hispanic/Latinx

Procedure

College students were informed they could earn extra credit in psychology undergraduate courses for participating in research studies. Interested participants were directed to an online survey to complete a modified, online Timeline Followback interview (Sobell & Sobell, 1992) followed by a Qualtrics survey. For the Timeline Followback, participants were shown a past-month calendar and asked to indicate which days they drank alcohol. Participants were encouraged to reference memory aids such as text messages, Snapchat memories, and photo captions. After indicating past-month drinking days, participants were shown singular webpages for each drinking day, which assessed day-level alcohol use, cannabis use, and negative alcohol consequences. After completion of the TLFB and the subsequent survey, participants were compensated one extra credit point and thanked for their time. The Arizona State University Institutional Review Board (IRB) approved all study procedures.

Timeline Followback Measures

Co-Use and Simultaneous Use. Participants reported if they used cannabis on drinking days (0=no, 1=yes) and if the effects of cannabis overlapped with those of alcohol (0=no, 1=yes).

Drinking Quantity. Participants reported how many standard drinks they consumed on drinking days from 1-20+ drinks. Participants were shown a standard drink chart when reporting on alcohol consumption, indicating that a standard drink is equal to 12 ounces of beer, 5 ounces of wine, or 1.5 ounces of liquor.

Negative Alcohol Consequences. Participants reported whether they experienced a list of 24 negative alcohol consequences on drinking days, which came from the Brief-Young Adult Alcohol Consequences Questionnaire (B-YAACQ; Kahler et al., 2005). Alcohol consequences covered domains of academic/occupational consequences, social/interpersonal consequences, physiological dependence, risky behavior, impaired control, blackout drinking, lack of self-care, and diminished self-perception. A sum of negative consequences was created for each day, ranging from 0 to 24. In addition, a binary indicator of each unique negative consequence domain was created for each day.

Data Analytic Plan

The current study used day-level latent profile analysis (LPA) to characterize data-driven profiles of alcohol-only and co-use days. Day-level LPA is a newer analytic approach, that characterizes days into profiles based upon day-level indicators of interest (Linden-Carmichael et al., 2022). Using a generalized estimating equations framework (GEE), day-level LPA corrects for nested data with a clustering statement, which accounts for clustering of days within participants. For the day-level LPA, profile solutions between 1 and 6 profiles were examined, and the optimal class solution was determined based upon AIC and BIC values, entropy values, the Lo-Mendell-Rubin Adjusted Likelihood Ratio Test (LLR), and by theoretical fit of the profile solution (Nylund et al., 2007). For the day-level LPA, intraclass means are given for continuous predictors (i.e., drinking quantity) and probabilities are given for binary predictors (i.e., co-use, SAM use), such that a 0% probability is indicative of the event never occurring on days within that profile, and a 100% probability is indicative of the event always occurring.

Once the optimal profile solution was determined, negative alcohol consequences were predicted by profile membership at the day-level. Specifically, the BCH method was used to predict distal outcomes from profile membership, which adjusts standard errors to account for classification error in the most likely profile membership (Asparouhov, & Muthén, 2014). Chi-square difference testing was used to test whether profiles differed on negative alcohol consequences

experienced each day. First, difference testing was used to determine if the number of alcohol consequences experienced at the day-level differed across profiles. Second, difference testing was used to compare whether the probability of experiencing unique alcohol consequences from the B-YAACQ differed across profiles; difference testing compared intraclass proportions of days within each profile in which each unique alcohol consequence was experienced vs. not experienced.

All models used Maximum Likelihood Estimation with Robust Standard Errors (MLR), and Full Information Maximum Likelihood was used to estimate missing data. The current analyses were not pre-registered, and data is available upon reasonable request.

RESULTS

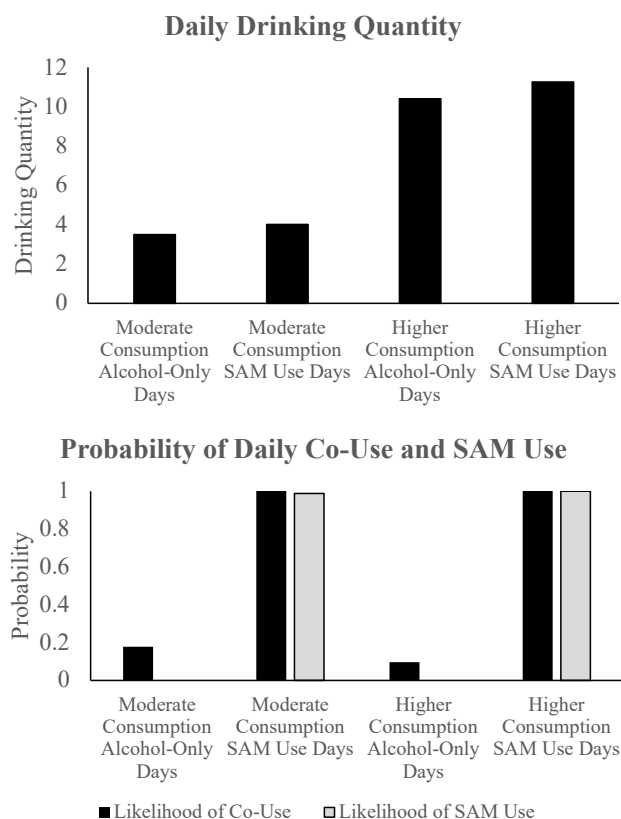
Day-Level Latent Profile Analysis

Profile solutions with 1 to 6 profiles were examined (see Table 1). AIC and BIC values declined across profiles, but Δ BIC leveled off after the 4-profile solution. Entropy values remained high across solutions (entropy > .86), and the LLR test was statistically significant for all solutions. The 5- and 6-profile solutions had individual profiles with <3% of the sample¹, whereas the 1-, 2-, 3-, and 4-profile solutions all had >6% of the sample in each profile. Thus, the 4-profile solution was deemed the best fit.

The first profile (N=2,030; 57.5%), named moderate consumption alcohol-only days, was indicative of moderate drinking quantity (M=3.49) coupled with a 17.9% probability of cannabis use and 0% probability of simultaneous use. The second profile (N=213; 6%), named higher consumption simultaneous use (SAM) days, was indicative of heavier drinking quantity (M=11.26) coupled with a 100% probability of cannabis use and simultaneous use. The third profile (N=1,027, 29%), named moderate consumption simultaneous use days, was indicative of moderate drinking quantity (M=4.01) coupled with a 100% probability of cannabis use and 98.7% probability of simultaneous use. Finally, the fourth profile (N=263, 7.4%), named higher consumption alcohol-only days, was indicative of heavier drinking quantity (M=10.42) coupled with a 9.6%

probability of cannabis use and 0% probability of simultaneous use (see Figure 1).

Figure 1. *Day-Level Latent Profiles*



Note. Likelihood of Co-Use and SAM Use is plotted on a 0-100% scale; moderate consumption alcohol-only days encompassed 57.5% of days, moderate consumption SAM use days encompassed 29% of days, higher consumption alcohol-only days encompassed 7.4% of days, and higher consumption SAM use days encompassed 6% of days across N=489 participants.

Prediction of Total Negative Alcohol Consequences

Higher consumption SAM use days were associated with more negative alcohol consequences than moderate consumption SAM use days, moderate consumption alcohol-only days, and higher consumption alcohol-only days. Moderate consumption SAM use days were associated with *less* negative consequences than higher consumption alcohol-only days but more negative alcohol consequences than moderate consumption alcohol-only days. Finally, higher consumption alcohol-only days were associated with more negative alcohol consequences than

¹It is worth mentioning that, when investigating the 5- and 6-profile solutions for theoretical fit, neither solution derived a profile indicative of co-use that was not simultaneous use.

moderate consumption alcohol-only days (see Table 2).

Prediction of Unique Negative Alcohol Consequences

Higher consumption SAM use days were associated with a greater likelihood of physiological dependence symptoms, but no other negative alcohol consequences, compared to higher consumption alcohol-only days. However, higher consumption SAM use days were associated with higher proportions of all alcohol consequences compared to moderate consumption SAM use and moderate consumption alcohol-only days, with the exception that higher consumption SAM use days did not differ from moderate

consumption SAM use days in the likelihood of experiencing lack of self-care consequences.

Higher consumption alcohol-only days were associated with a higher proportion of all alcohol consequences compared to moderate consumption SAM use and moderate consumption alcohol-only days, with the exception that higher consumption alcohol-only days did not differ from moderate consumption SAM use days with respect to academic-occupational, lack of self-care, and diminished self-perception consequences. Finally, moderate consumption SAM use days were associated with greater likelihood of blackouts, lack of self-care, impaired control, and social-interpersonal consequences compared to moderate alcohol only days (see Table 2).

Table 1. *Model Fit Indices for Day-Level Latent Profile Analysis*

	AIC	BIC	ΔBIC	LLR	LMR Test	Entropy	% in each class
1 Class	28103.052	28,127.73		-14047.526		1	100
2 Class	25284.702	25334.061	2,793.67	-12634.351	< .001	1	65, 35
3 Class	24959.562	25033.6	300.461	-12467.781	0.02	0.926	58, 31, 11
4 Class	24494.267	24592.986	440.614	-	< .001	0.916	58, 29, 7, 6
				12231.134			
5 Class	24421.298	24544.696	48.29	-12190.649	0.01	0.909	53, 27, 10, 8, 2
6 Class	24219.486	24367.564	177.132	-12085.743	0.004	0.86	45, 25, 14, 7, 6, 3

Note. LMR = Lo-Mendell-Rubin Log-likelihood Ratio Test; The 4-class solution deemed to have the best fit.

Table 2. *Comparison of Means and Interclass Proportions by Day-Level Profiles*

	Higher Consumption SAM Days	Moderate Consumption SAM Days	Higher Consumption Alc-Only Days	Moderate Consumption Alc-Only Days
Total Alcohol Consequences	6.411 ^{a,b,c}	2.170 ^{d,e}	4.726 ^f	1.635
Academic-Occupational Consequences	0.295 ^{a,c}	0.125	0.187 ^f	0.103
Social/Interpersonal Consequences	0.467 ^{a,c}	0.185 ^{d,e}	0.493 ^f	0.133
Diminished Self-Perception	0.275 ^{a,c}	0.119	0.159 ^f	0.096
Lack of Self-Care	0.510 ^c	0.406 ^e	0.482 ^f	0.269
Risky Behaviors	0.493 ^{a,c}	0.115 ^d	0.383 ^f	0.093
Impaired Control	0.569 ^{a,c}	0.246 ^{d,e}	0.454 ^f	0.192
Blackout Drinking	0.751 ^{a,c}	0.258 ^{d,e}	0.665 ^f	0.205
Physical Dependence	0.534 ^{a,b,c}	0.177 ^d	0.352 ^f	0.145

Note. a = means for moderate consumption SAM differs from moderate consumption SAM, b = higher consumption SAM differs from higher consumption alcohol-only, c = higher consumption SAM differs from moderate consumption alcohol-only use, d = moderate consumption SAM use differs from higher consumption alcohol-only use, e = moderate consumption SAM use differs from moderate consumption alcohol-only, and f = higher consumption alcohol-only differs from moderate consumption alcohol-only significantly at the $p < .05$ level.

DISCUSSION

In the current study, a day-level LPA identified four profiles of day-level use behavior, indicative of moderate consumption alcohol-only and SAM use days, as well as higher consumption alcohol-only and SAM use days. Moderate consumption days ranged between 3.5-4 drinks, and higher consumption days ranged between 10.4-11.3 drinks. Thus, the day-level LPA did not generate a lower-risk profile where 1-2 drinks were consumed. In addition, both higher and moderate consumption co-use days were characterized by a high likelihood of simultaneous use on each day, suggesting that, with a data-driven approach, the current study was not able to separate co-use from simultaneous use days. Most days were moderate consumption alcohol-only (57.5%) or moderate consumption SAM use (29%), compared to higher consumption alcohol-only (7.4%) and higher consumption SAM use (6%) days.

Higher consumption SAM use days were associated with more negative alcohol consequences than any other day-level profile, including higher consumption alcohol-only days. Thus, in contrast to Mallett et al. (2019), the current study found that, at nearly equivalent levels of higher-risk alcohol consumption (i.e., higher consumption co-use days $M=11.26$; higher consumption alcohol-only days $M=10.42$), co-use of cannabis conferred risk for day-level negative alcohol consequences. However, it is important to note that, when testing unique alcohol consequences, the only pairwise difference between higher consumption SAM use and higher consumption alcohol-only days was for acute dependence symptoms. Alternatively stated, higher consumption SAM use (vs. alcohol-only) days were associated with the highest severity alcohol consequence (i.e., dependence symptoms) but not necessarily lower-severity alcohol consequences (i.e., academic/occupational, risky behavior).

In line with study hypotheses, higher consumption alcohol-only days were associated with more negative alcohol consequences than both moderate consumption alcohol-only and moderate consumption SAM use days. Thus, the current results support the notion that there are

in fact moderate consumption SAM use days, and that heavier alcohol consumption days increase risk compared to lower consumption days, even when cannabis is simultaneously/co-used. Furthermore, in terms of unique alcohol consequences, pairwise differences suggested that higher consumption alcohol-only days vs. moderate consumption SAM use days conferred risk for dependence symptoms, blackout drinking, impaired control, risky behavior, and social/interpersonal consequences, but not lack of self-care, diminished self-perception, or academic/occupational consequences. One interpretation of such findings is that higher consumption alcohol-only days vs. moderate consumption co-use days differ in behavioral and interpersonal consequences (e.g., social/interpersonal consequences, risky behavior, impaired control), whereas negative consequences that are more internalized and self-specific (i.e., a lack of self-care, diminished self-perception, academic/occupational consequences) are relatively similar across these days.

Findings may inform prevention efforts. First, results suggest that higher-risk day-level co-use and alcohol-only patterns were relatively infrequent, encompassing only 7.4% and 6% of days, respectively. Thus, testing earlier-day predictors of higher-risk alcohol-only and co-use days may inform intervention development to reduce negative alcohol consequences on these infrequent yet riskier days. Similarly, results suggest that targeted interventions on heavier use days, particularly those when alcohol and cannabis is co-used, may be particularly important. Just-in-time interventions may benefit from frequent assessment of alcohol consumption and the presence of cannabis use during a drinking episode, as such interventions could use motivational tactics (i.e., personalized feedback, goal-directed behavior; Rollnick & Miller, 1995) to curb riskier behavior. In addition, findings point to increased risk in several behavioral and interpersonal consequences on higher risk days, such as impaired control, risky behavior, and social/interpersonal consequences. Therefore, just-in-time interventions that motivate the use of protective behavioral strategies may also be effective at reducing negative alcohol consequences on higher-risk days. However, future intervention research is needed to test these assertions.

Although the current study yielded novel insights, the findings must be interpreted in light of limitations. First, the current study used day-level data from a timeline-followback, and thus responses may have been subject to recall bias. However, studies suggest that the timeline followback is a reliable way to assess past 30-day alcohol use, cannabis use, and negative alcohol consequences (e.g., Carey, 1997; Merrill et al., 2020; Searles et al., 2002). Second, the current study did not assess cannabis use quantity, and it is possible that co-use days may have differed based upon amount of cannabis used (e.g., Stevens et al., 2021). Unfortunately, cannabis use quantity is difficult to assess (e.g., Hindocha et al., 2018), but future research in this area is needed. Similarly, the current study did not assess negative cannabis consequences, which may differ from negative alcohol consequences. Since most of the literature focuses on negative alcohol consequences, future research on negative cannabis consequences is warranted. Third, the current study did not compare co-use days to cannabis-only days as the timeline followback only asked about cannabis use on drinking days. Thus, future research is also needed to test similar models comparing co-use to cannabis-only days. Finally, the current findings were in a college student sample and future research should replicate findings in community samples.

In summary, the current findings suggest that higher consumption SAM use days are associated with the highest levels of daily negative alcohol consequences, but higher consumption SAM use days differed from higher consumption alcohol-only days only in terms of physiological dependence symptoms. In addition, lower consumption SAM use days were associated with significantly fewer negative alcohol consequences than higher consumption alcohol-only days, suggesting that there are, in fact, lower-risk co-use days. Findings suggest that relations among day-level SAM use (vs. alcohol-only use) are complex, and that heaviness of alcohol consumption (with or without SAM use) is a strong, and perhaps primary driver of day-level negative alcohol consequences.

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