Cannabis
2024, Volume 7 (1)

researchmj.org
10.26828/cannabis/2023/000184

Latent Classes of Simultaneous Alcohol and Cannabis Use and Associations with Consequences using Daily Data

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ABSTRACT

Objective: Simultaneous alcohol and cannabis use (i.e., marijuana, [SAM], using alcohol and cannabis so effects overlap) is associated with increased consumption and consequences compared to single-substance use. SAM use prevalence is increasing, yet there is heterogeneity in use patterns among those engaging in SAM use, which may lead to differential consequences. **Method**: This study drew on daily data to characterize latent profiles of cannabis, alcohol, and SAM use patterns and to test class differences on related consequences after 3 months among college students engaging in SAM use (77.08% White, 51.67% female). Class indicators were 10 person-level substance use variables derived from repeated daily surveys. **Results**: Results yielded a three-class solution: Heavy Alcohol, Cannabis, and SAM (Heavy Use, $n = 105$); Heavy Alcohol-Light Cannabis ($n = 75$); and Light Alcohol-Heavy Cannabis ($n = 60$). There were significant person-level differences between classes on all substance use indicators (e.g., quantity and frequency of alcohol, cannabis, and SAM) but not sex or race/ethnicity. At 3-month follow-up, the Heavy Use class endorsed more SAM consequences than the other classes. The Heavy Use class did not differ on alcohol or cannabis consequences compared to the Heavy Alcohol-Light Cannabis or Light Alcohol-Heavy Cannabis classes, respectively. The Light Alcohol-Heavy Cannabis class endorsed the fewest alcohol consequences. The Heavy Alcohol-Light Cannabis class endorsed the fewest cannabis consequences. **Conclusions**: Findings highlight distinct patterns of co-use and their association with consequences at follow-up. Heavy alcohol or cannabis use was associated with consequences for that substance, but heavy use of only one substance was not indicative of SAM-specific consequences.

Key words: = simultaneous use; cannabis; alcohol; latent class analysis

Simultaneous alcohol and cannabis (i.e., marijuana [SAM]) use refers to the use of both substances such that the effects overlap. SAM use is particularly prevalent among college-aged individuals (i.e., 18 – 22 years; Terry-McElrath & Patrick, 2018; White et al., 2019) with a large, nationally representative sample finding that approximately one-quarter of college students enrolled in 4-year universities endorse lifetime SAM use (McCabe et al., 2021). Further, 54% of college students endorsing past-year alcohol use and 73% of those endorsing past-year alcohol and cannabis use report at least one occurrence of SAM use in the past year (Patrick & Lee, 2018; White et al., 2019). Importantly, the prevalence of SAM use increases as the frequency of heavy episodic drinking (i.e., consuming 4 or more drink for females and 5 or more drinks for males a session; HED) and cannabis use increase (Miech et al., 2018), suggesting that increased alcohol, cannabis, and SAM use patterns are related.

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As rates of SAM use increase, individuals are at increased risk of incurring negative consequences of use. Compared to single-substance use, SAM use is associated with greater frequency of both alcohol and cannabis use, greater consequences of use, greater functional impairment (see Lee et al., 2022 and Yurasek et al., 2017 for reviews), and increased risk of mental health symptoms (Thompson et al., 2021). Within persons studies comparing SAM use to alcohol-only use have found that SAM use is related to increased number of consequences, alcohol quantity, and alcohol and cannabis frequency (Jackson et al., 2020; Lee et al., 2020; Linden-Carmichael et al., 2020). Comparing SAM to concurrent use (i.e., use of cannabis and alcohol such that the effects do not overlap), those reporting SAM use endorse more cannabis consequences and greater quantity and frequency of both alcohol and cannabis use (Looby et al., 2021). Of note, however, those endorsing SAM use did not significantly differ on cannabis consequences or cannabis frequency and quantity compared to those reporting cannabis-only use (Looby et al., 2021). Though there are differences in outcomes between SAM and concurrent use, it is worth noting that the majority of alcohol and cannabis co-use is SAM (Patrick et al., 2019; Sokolovsky et al., 2020; Subbaraman & Kerr, 2015), highlighting the importance of understanding specific patterns of this type of co-use. Taken together, these findings indicate that there may different patterns of risk for individuals based on their unique cannabis, alcohol, and SAM use patterns.

The Role of Alcohol and Cannabis Use Behavior in SAM outcomes

Though studies have established that increased SAM use is associated with negative outcomes, it is important to consider how quantity and frequency of alcohol and cannabis use independently influence these relations. Extant work comparing single-substance use and co-use have included frequency and/or quantity as covariates with inconsistent outcomes. Within- (Lee et al., 2020; Lipperman-Kreda et al., 2017; Mallet et al., 2019; Sokolovsky et al., 2020) and some between-person designs have found that relations between SAM use and outcomes (e.g., consequences, driving under the influence) are attenuated or even eliminated when frequency of individual substance use is controlled for (Cummings et al., 2019). However, other work has found that SAM use incurs increased risk for adverse cannabis and alcohol outcomes after controlling for single-substance use (Jackson et al., 2020; Patrick et al., 2019; Subbaraman & Kerr, 2015), frequency and baseline problems (Briere et al., 2011). In addition to frequency, quantity may also impact relations between SAM and outcomes. Among college students, relations between SAM use and negative consequences were greatest among those who engaged in HED during event-level SAM use occasions compared to lower alcohol quantities (Mallett et al., 2019). Of note, these authors found that heavy drinking was associated with increased consequences and that this pattern did not differ as a function of whether the person used cannabis simultaneously. Similarly, Metrik et al. (2016) found that SAM use with heavy drinking, but not moderate drinking, was associated with increased likelihood of unprotected sex. Among those endorsing SAM use, there were similar consequence endorsement on alcohol-only days as compared to SAM days (Sokolovsky et al., 2020). These findings suggest that differences in consequences may be most attributable to drinking patterns (i.e., quantity and frequency) as opposed to cannabis use patterns.

There are several possible explanations for the above patterns. First, college students may be more inclined to attribute negative consequences of SAM use to alcohol alone (Jackson et al., 2020) despite laboratory tasks demonstrating greater functional impairment with SAM use than alcohol- or cannabis-only use (Downey et al., 2013; Yurasek et al., 2017). Additionally, it could be that ordering effects matter. At the person-level, days with cannabis-initiated SAM use were associated with increased cannabis consumption but decreased alcohol consumption; however, ordering effects were not related to day-level consequences (Gunn et al., 2021). Cross-sectionally, Karoly et al. (2022) found that on co-use days, an increase in cannabis-initiated days was associated with fewer alcohol consequences, whereas an increase in alcohol-initiated days was associated with fewer cannabis consequences.

As can be seen, there is clear heterogeneity in patterns of alcohol, cannabis, and SAM use among those engaging in SAM use. Quantity and

frequency of individual substance use at the event- and person-level differentially relate to experiences of consequences; however, associations between use patterns and outcomes have yielded inconsistent results. Notably, much of the extant literature on SAM use and outcomes has utilized variable-centered approaches in which analyses test coarse relations between variables (Laursen & Hoff, 2006). An alternative method for elucidating relations between SAM use patterns and outcomes is to employ a person-centered approach wherein the focus is on parsing out typologies or patterns of multiple indicators to create classes or categories. Use of a person-centered approach allows for examination of how these patterns of use may relate to risk of consequences more holistically, rather than examining relations between specific use variables (e.g., quantity, frequency) as they relate to consequences. Latent class analysis (LCA) accounts for individual differences in use at the person-level to determine unique patterns of use (i.e., classes) that then can be used to compare differences in outcomes. Importantly, though it is well-established that SAM use is associated with greater risk of incurring negative consequences at the event- or day-level, individuals tend to have a pattern of alcohol, cannabis, and SAM use that may be evident by looking at their behavior over time and that is predictive of long-term consequences.

To date, two studies of SAM use have utilized class analyses to examine patterns of alcohol and cannabis co-use. First, in a sample of adolescents, Patrick et al. (2018) identified a four-class solution of alcohol and cannabis use: SAM HED, SAM without HED, concurrent alcohol and cannabis-only, and alcohol-only. Being in either SAM class was associated with increased likelihood of additional substance use and conduct problems and this relationship was stronger for the SAM with HED group. Importantly, though SAM use was an indicator in the class solution, their analyses were not specific to those endorsing SAM use. Given the evidence supporting increased risk of adverse outcomes among those endorsing SAM, it is crucial to understand unique patterns of use within a population that engages in SAM. To that end, using the same sample as the present study, Lanza et al. (2022) found a five-class solution: frequent cannabis-focused SAM use, frequent alcohol-initiating SAM use, heavy-drinking infrequent SAM use, moderate SAM use, and light infrequent SAM use. Classes primarily showed differences in frequency of SAM use and alcohol behaviors. Of note, however, consequences were included as a class indicator rather than an outcome variable for class membership. As such, it is unclear to what degree the classification of SAM use among college-aged students was driven by the consequences of such use as opposed to use patterns themselves. Use of LCA to examine typologies of cannabis, alcohol, and SAM use could serve to provide nuanced understanding of how individual patterns of substance use over time among individuals who engage in SAM use relate to experiences of long-term consequences.

Current Study

The purpose of the present study is to characterize patterns of SAM use based on alcohol, cannabis, and SAM behaviors (e.g., quantity, frequency) and investigate if these classes are associated with experiences of alcohol, cannabis, and SAM consequences at 3-month follow-up. As the reviewed literature demonstrates, when included as covariates, alcohol quantity and frequency impact relations between SAM use and consequences (e.g., Lee et al., 2020; Lipperman-Kreda et al., 2017; Mallet et al., 2019) and when participants are stratified by alcohol quantity, individuals engaging in HED appear at greater risk for adverse outcomes (e.g., Mallett et al., 2019; Metrik et al., 2016; Patrick et al., 2018). Notably, much of the extant work examines event- or day-level consequences. However, understanding individuals' patterns of use over a longer period of time adds to our understanding of how specific cannabis, alcohol, and SAM behaviors may impact consequences over time. It could be that there are individuals who engage in high frequency use of one substance with occasional use of the other substance and, thus, may differentially experience consequences of use. To that end, we hypothesized that distinct classes would emerge based on quantity and frequency of alcohol, cannabis, and SAM use. Further, it was hypothesized that individuals with the heaviest use of both alcohol and cannabis in addition to greatest SAM use frequency would experience the greatest risk for consequences.

METHODS

Participants

Participants were college students in a multi-site study assessing simultaneous cannabis and alcohol use. Data collection took part in four stages. Baseline data were collected in the fall of 2017 and follow-up assessments were completed approximately three months later (see White et al., 2019 for details). Following the baseline survey, individuals who reported at least one SAM use occasion in the past 3-months were invited to participate in a daily survey study. Of those eligible, 89% (N = 284) participated, completing two bursts of up to five surveys per day over 28 consecutive days following the baseline and 3-month follow-up surveys (see Stevens et al., 2020 for details). Data for the present study utilized a subsample of individuals who completed the baseline survey, first daily burst, and the 3-month follow-up survey to establish temporal precedence between class solutions (i.e., daily data) and consequences at the follow-up survey (N= 240). At baseline, participants included in the analyses had a mean age of 19.9 years and the majority of participants self-identified as non-Hispanic White (77.1%) and female (51.7%). All procedures were approved by the coordinating university's Institutional Review Board.

Measures

Baseline Measures. Demographic variables were collected at baseline. Participants reported on their race using census categories. Additionally, ethnicity was coded such that 0 = not Hispanic/Latinx and 1 = Hispanic/Latinx. Due to limited endorsement, a binary race/ethnicity variable was created (0 = non-Hispanic White). Sex assigned at birth was coded as 0 = male, 1 = female. Age was treated as a continuous variable.

Daily Survey Items. Participants completed up to five surveys per day over 28 days during the first burst. Due to technical difficulties on the first two days of daily data collection, the first burst was limited to 26 days of daily survey data. Because LCA requires categorical indicators, variables were aggregated to the person-level such that dichotomous indicators in the final data represented any instance of the behavior for a participant across all study days while categorical indicators represented participants' quartile in a continuous variable averaged across all observations. Ten variables were included as latent class indicators. Class indicators were selected to capture a range of behaviors associated with experiences of consequences including quantity and frequency of use as well as substance-specific indicators associated with negative outcomes such as heavy drinking, use of multiple cannabis forms in a day, and ordering of alcohol and cannabis on SAM occasions. For alcohol variables, cut-offs for dichotomization were selected based on NIAAA guidelines for high-risk drinking with variables created to reflect both HED (4+ drinks for men, 5+ drinks for women) and severe impairment (i.e., estimated blood alcohol concentration [eBAC] ≥ .16; NIAAA, 2022). To account for event- and day-level variability, categorical variables were derived to reflect average quantity and frequency of alcohol, cannabis, and SAM use using quartiles to create cut-off points.

Alcohol variables included eBAC ≥ .16 on any use day (0 = no, 1 = yes); any HED on an alcohol-only day (0 = no, 1 = yes), any HED on any SAM day (0 = no, 1 = yes), average drinks per drinking day (0 = ≤ 4, 1 = 4.01 – 6.00, 2 = > 6), and proportion of use days with any alcohol use (0 = .00 - .25, 1 = .26 = 50, 2 = .51 - .75, 3 = .76 – 1.00). Cannabis variables included average cannabis uses per use day (0 = 1.00 – 2.00, 1 = 2.01 – 4.00, 2 = > 4), use of two or more cannabis forms on any cannabis-use day (0 = no, 1 = yes), and proportion of use days with any cannabis use (0 = .00 - .25, 1 = .26 = 50, 2 = .51 - .75, 3 = .76 – 1.00). SAM variables included frequency of SAM use (0 = 1 – 2 days, 1 = ≥ 3 days) and proportion of SAM use days initiated with alcohol (0 = .00 - .25, 1 = .26 = 50, 2 = .51 - .75, 3 = .76 – 1.00). For the present study, SAM use was defined as occasions in which alcohol and cannabis were used within a 3-hour (180 minute) period. Using this operationalization, approximately 90% of co-use days were SAM use days.

In addition to the class indicators, classes were compared on an additional seven person-level exploratory (auxiliary) variables. Items included as exploratory were selected to further capture potential differences in substance use patterns between groups without influencing the class estimations. Four categorical items were created to examine person-level proportions of days with no alcohol or cannabis use; use days with any

alcohol use; use days with any cannabis use; and use days with SAM use (0 = .00 - .25, 1 = .26 = 50, 2 = .51 - .75, 3 = .76 – 1.00). Though proportion of total days was included as a class indicator, proportion of use days with differing substances used may provide additional nuanced information on alcohol, cannabis, and SAM patterns. Further, to examine consistency in quantity of alcohol and cannabis use, three continuous variables were created, examining standard deviations in daily drinks per drinking day, day-level loose leaf quantity on days with any loose-leaf cannabis use among those endorsing flower use, and day-level cannabis concentrates quantity on days with concentrate use. Given the exploratory nature of standard deviations of substance use, inclusion of these markers of variability as exploratory variables allowed for examination of these variables as continuous rather than creating categorical ranges of standard deviations in quantity and frequency of use that would be required for an LCA model.

Follow-up Measures. Past 3-month alcohol, cannabis, and SAM consequences were assessed via a follow-up survey approximately three months post-baseline. Consequences were from a measure collapsing items across from the Brief Young Adult Alcohol Consequences Questionnaire (BYAACQ; Kahler et al., 2005) and the Brief Marijuana Consequences Questionnaire (B-MACQ; Simons et al., 2012), resulting in 28 total items. Items were presented such that individuals endorsed whether they experienced a consequence and if so, if they attributed the consequence to alcohol, cannabis, and/or SAM. Participants were able to select multiple attributions per consequences resulting in three individual total consequences scores for alcohol, cannabis, and SAM. This approach has demonstrated good internal consistency with alpha values ranging from .87 to .88 (see Jackson et al., 2020). Values for each consequence attribute type ranged from 0 to 28 with higher scores representing more problems. Both the BYAACQ and B-MACQ have demonstrated good internal consistency with college students (Kahler et al., 2005; Simons et al., 2012).

Analytic Approach

Indicators were included in a latent class analysis using MPlus version 7.31 (Muthen & Muthen 1998 – 2017). Classes were determined using the maximum likelihood with robust standard errors (MLR) with 200 random starts. Model fit was evaluated using Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the sample-size adjusted BIC (BIC_{adj}), with lower values indicating better fit and entropy with higher values indicating better fit. In addition, the sample size of each class was taken into consideration (O'Donnell et al., 2017; Shanahan et al., 2013). Upon determination of the optimal class solution, differences between classes on class indicators and additional variables of interest (e.g., demographics, proportion of use days with any alcohol or any cannabis use) were compared using the method initially developed by Bolck, Croon, and Hagenaars (BCH method; Bolck et al., 2004; Asparouhov & Muthen, 2021). Lastly, using the training weights (i.e., latent variables accounting for measurement error in the indicators) derived from the class analysis, class membership was used to predict the number of consequences using the approach developed by Asparouhov and Muthen (2021).

RESULTS

Comparison of class solutions specifying 1 – 6 classes found that the 3-class solution evinced the best fit to the data based on the AIC, BIC, BIC_{adj} and log likelihood replication (see Table 1).

Table 1. *Latent Class Analysis Model Fit Indices*

Number of Classes	AIC	BIC	Adjusted BIC	Entropy
1	3095.706	3137.473	3099.436	-
2	2935.228	3022.244	2943.000	.82
3	2818.021	2950.286	2829.835	.89
4	2790.998	2968.511	2806.853	.84
5	2795.679	3018.440	2815.576	.86
6	2800.379	3068.388	2824.317	.90

This solution resulted in an entropy of .89, suggesting good distinction among classes. Though the four-class solution yielded a lower AIC, coverage of classes was poor (i.e., class 4 only comprised 2% [$n = 5$] of total sample). As such, the three-class solution was selected as it maximized fit and entropy metrics while also permitting better coverage across classes. The heavy alcohol, cannabis, and SAM (hereafter referred to as "Heavy Use") class (n = 105) was made up of individuals endorsing heavy and frequent use of alcohol, cannabis, and SAM. Additionally, on SAM use days, these individuals were equally likely to initiate with alcohol or cannabis. The Light Alcohol-Heavy Cannabis class (n = 60) contained individuals endorsing infrequent, low quantity alcohol use but frequent, higher quantity of cannabis use, use of multiple cannabis forms and moderate SAM endorsement typically initiated with cannabis. Conversely, the Heavy Alcohol-Light Cannabis class (n = 75) comprised individuals with heavy, frequent alcohol use, infrequent, low quantity cannabis use, and relatively low endorsement of SAM use, which was predominately alcohol-initiated (see Table 2 and Figure 1).[1]

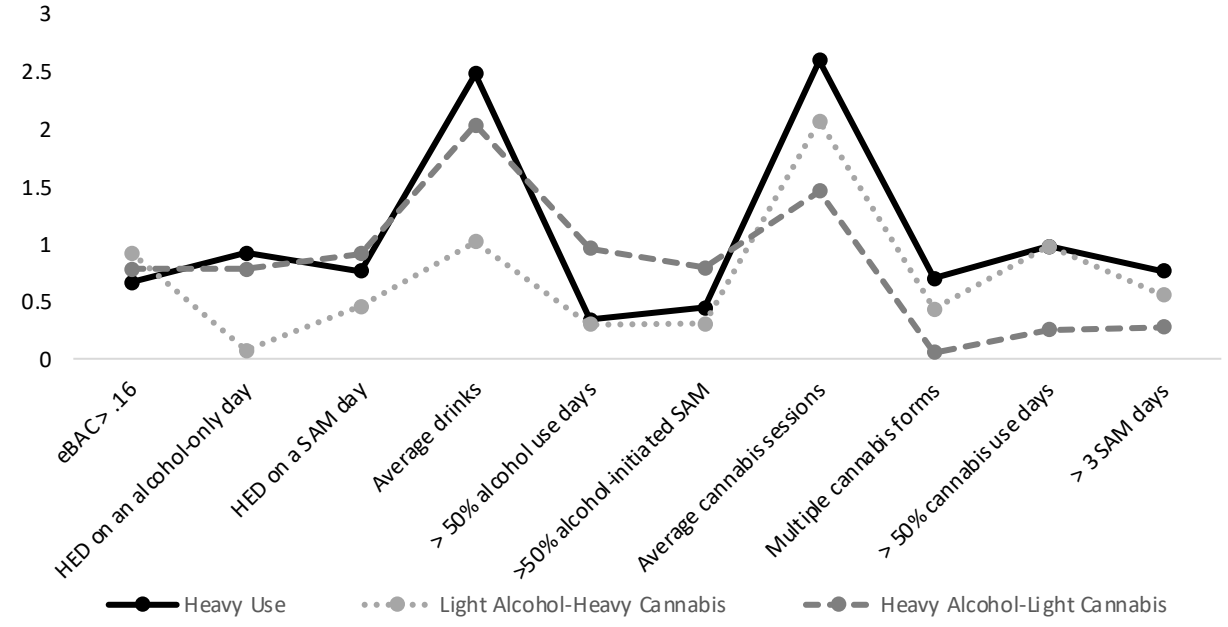
Table 2. *Latent Class Indicator Endorsement Rates and Alcohol, Cannabis, and SAM Consequences at Follow-Up for the Full Sample and the Latent Classes*

Indicator	Full Sample N = 240	Heavy Alcohol, Cannabis, and SAM N = 105	Light Alcohol-Heavy Cannabis N = 60	Heavy Alcohol-Light Cannabis N = 75
eBAC ≥ .16 on ≥ 1 day				
No	.329	.075	.923	.213
Yes	.671	.925	.077	.787
HED on an alcohol only day				
No	.239	.234	.538	.082
Yes	.761	.766	.462	.918
HED on a SAM day				
No	.188	.020	.427	.231
Yes	.812	.980	.573	.769
Average drinks per drinking day				
≤ 4	.342	.086	.865	.283
4.01 – 6.00	.333	.400	.135	.397
> 6	.325	.514	.000	.320
Average daily cannabis sessions on cannabis use days				
1.00 – 2.00	.250	.083	.187	.530
2.01 – 4.00	.388	.269	.546	.427
> 4.00	.362	.649	.268	.043
Frequency of SAM use				
1 – 2	.438	.233	.440	.717
3+	.562	.767	.560	.283

[1]Class analyses were conducted using all available survey days with a total of 5863 survey days across 240 participants. To ensure class solutions were not impacted by missing surveys within days, class analyses were conducted on a subsample comprised of days with only 100% coverage (i.e., no two sequential missed prompts resulting in missing reporting periods; 75.61% of total survey days). This resulted in 4480 survey days across 209 participants. The class solution for the full coverage only subsample closely approximated the solution for the full sample. Both analyses resulted in a three-class solution with similar endorsement proportions for each indicator by class. As such, the results for the full sample are presented.

Multiple forms of cannabis on a use day				
No	.567	.295	.565	.942
Yes	.433	.705	.435	.058
Proportion of use days with any alcohol use				
.00 - .25	.171	.204	.329	.000
.26 - .50	.300	.454	.366	.037
.51 - .75	.221	.247	.214	.191
.76 – 1.00	.308	.095	.091	.773
Proportion of use days with any cannabis				
.00 - .25	.117	.000	.018	.355
.26 - .50	.129	.016	.000	.386
.51 - .75	.158	.107	.194	.200
.76 – 1.00	.596	.876	.788	.058
Proportion of SAM days with alcohol first				
.00 - .25	.296	.350	.433	.113
.26 - .50	.179	.200	.255	.090
.51 - .75	.175	.288	.118	.064
.76 – 1.00	.350	.161	.194	.733
Mean (SD) alcohol consequences at 3-month follow-up	7.44 (5.07)	8.05 (5.4)	5.23 (3.49)	8.06 (5.09)
Mean (SD) cannabis consequences at 3-month follow-up	6.11 (4.39)	6.71 (4.60)	7.63 (4.05)	3.85 (3.36)
Mean (SD) SAM consequences at 3-month follow-up	4.49 (4.17)	5.41 (4.45)	3.71 (4.47)	3.51 (2.75)

Figure 1. *Latent Class Indicator Endorsement by Class*



Next, classes were compared to determine if they significantly differed on each of the class indicators (see Table 3). The Heavy Use class had the highest proportion of individuals with at least one day of eBAC ≥ .16, any HED on a SAM day, three or more SAM use days, and use of two or more cannabis forms. Additionally, this class had a greater average number of drinks per drinking day and more cannabis uses per cannabis day than the Heavy Alcohol-Light Cannabis or Light Alcohol-Heavy Cannabis classes. The Light Alcohol-Heavy Cannabis class had the lowest proportion of individuals with at least one day of eBAC ≥ .16, HED on an alcohol-only day, and HED on a SAM day. The Heavy Alcohol-Light Cannabis class endorsed the highest proportion of HED on an alcohol-only day and the highest rates of alcohol-initiated SAM use, but the lowest proportion of individuals with three or more SAM use days and use of two or more cannabis forms.

In addition to the class indicators, several additional variables were compared between classes. These variables included: proportions of days with no substance use and proportion of use days with any alcohol use, any cannabis use, and SAM use (person-level); degree of variation (i.e., standard deviations at the day-level) in alcohol (number of drinks) and cannabis quantity (loose leaf and concentrates); and demographics (person-level; see Table 3).

Table 3. *Comparisons of Means on Latent Class Indicators and Additional Variables by Class*

Indicator	Heavy Alcohol, Cannabis, and SAM	Light Alcohol-Heavy Cannabis	Heavy Alcohol-Light Cannabis
eBAC ≥ .16 on ≥ 1 day[a,b,c]	.966	.014	.803
HED on an alcohol only day[a,b,c]	.768	.444	.922
HED on a SAM day[a,b,c]	.998	.541	.770
Average drinks per drinking day[a,b,c]	1.489	0.026	1.038
Average daily cannabis sessions on cannabis use days[a,b,c]	1.604	1.074	0.465
Frequency of SAM use[a,b,c]	1.786	1.546	1.267
Multiple forms of cannabis[a,b,c]	.734	.411	.036
Proportion of SAM days with alcohol initiation[b,c]	1.225	1.058	2.477
Proportion of use days with any alcohol use[b,c]	1.221	1.033	2.779
Proportion of use days with any cannabis use[a,c]	2.889	2.791	0.891
Proportion of no use days[a,b,c]	.265	.370	.607
Proportion of use days with SAM use[a,b]	0.765	0.507	0.419
Average standard deviation in drinks per drinking day[b,c]	4.378	1.564	3.388
Average standard deviation in loose leaf quantity on use days[b,c]	.662	.472	.150
Average standard deviation in concentrate quantity on use days[b,c]	3.859	3.081	0.627
Age[a]	19.68	20.20	19.88

Note. Bold indicates variable was an indicator in the latent class analysis.
[a] = classes 1 and 2 significantly differ, [b] = classes 1 and 3 significantly differ, [c] = classes 2 and 3 significantly differ. There were no significant differences on sex or race/ethnicity between classes.

Due to the exploratory nature of these variables and in order to maximize parsimony of the class solution, these variables were not included as class indicators, but were entered as additional variables to facilitate comparison without influencing the class solutions. The Heavy Use class had the lowest proportion of no use days and the Heavy Alcohol-Light Cannabis use class had the highest proportion. However, on use days, the Heavy Alcohol-Light Cannabis class had the greatest proportion of days with any alcohol use and the lowest proportion of days with any cannabis use. Regarding standard deviations in day-level quantity of use, the Light Alcohol-Heavy Cannabis use demonstrated the lowest deviations in typical drinks per drinking day (i.e., greatest consistency) but the Heavy Alcohol-Light Cannabis class had the lowest standard deviations in both day-level cannabis flower use and concentrate quantity. The classes did not differ on sex, race/ethnicity, but the Light Alcohol-Heavy Cannabis class was older than the Heavy Use class.

Class Membership and Consequences

There were several significant differences in the three types of consequences at 3-month follow-up as a function of class membership (see Table 2 for means and standard deviations). Compared to the Heavy Use class, the Light Alcohol-Heavy Cannabis class endorsed significantly fewer alcohol and SAM consequences but did not differ on cannabis consequences (see Table 4). The Heavy Alcohol-Light Cannabis class endorsed fewer cannabis and SAM consequences, but similar rates of alcohol consequences compared to the Heavy Use class. Lastly, compared to the Light Alcohol-Heavy Cannabis class, the Heavy Alcohol-Light Cannabis class endorsed significantly more alcohol consequences but fewer cannabis consequences. However, these classes did not differ on SAM consequences at follow-up.[2]

Table 4. *Number of Consequences as a Function of Class Membership*

	Alcohol Consequences		Cannabis Consequences		SAM Consequences	
	b	*p*	b	*p*	b	*p*
Heavy Use (ref) v. Light Alcohol-Heavy Cannabis	-2.776	.003	0.889	.264	-1.667	.040
Heavy Use (ref) v. Heavy Alcohol-Light Cannabis	0.004	.997	-2.839	<.001	-1.830	.026
Light Alcohol-Heavy Cannabis (ref) v. Heavy Alcohol-Light Cannabis	2.780	.006	-3.729	<.001	-0.163	.860
Race/ethnicity (ref = Non-Hispanic White)	-0.158	.848	0.663	.379	0.912	.256
Sex (ref = male)	0.490	.490	-0.322	.605	0.667	.322
Age	-0.033	.906	-0.124	.624	0.043	.877

[2]Ordinal logistic models are presented for all consequence outcomes. However, cannabis consequences evinced skewed distribution (mean = 3.3, SD = 41) with zero-inflation (N = 292, 31.5%). As such, zero-inflated Poisson models were conducted for cannabis consequences. Similar to the ordinal regressions, the Heavy Use class did not significantly differ from the Light Alcohol-Heavy Cannabis class on cannabis consequences (b = .90, p = .55). However, differences between the Heavy Use and Heavy Alcohol-Light Cannabis classes (b = -2.19, p = .08) and Light Alcohol-Heavy Cannabis and Heavy Alcohol-Light Cannabis classes (b = -1.29, p = .27) were no longer significant.

DISCUSSION

The primary purpose of the present work was to examine typologies of alcohol and cannabis use among individuals engaging in SAM use and how class membership relates to consequences at 3-month follow-up. Latent classes analysis yielded a three-class solution: Heavy Use, Heavy Alcohol-Light Cannabis, and Heavy Cannabis-Light Alcohol. Broadly, these classes suggest that amongst those engaging in SAM use, there are individuals who primarily engage in frequent cannabis use but less frequent and heavy alcohol use. Conversely, there is a group of individuals demonstrating a pattern of heavy alcohol use with infrequent, light cannabis use. Notably, over one-third of the sample demonstrated a pattern of heavy, frequent alcohol, cannabis, and SAM use. Classes were differentially related to alcohol, cannabis, and SAM consequences at follow-up.

The Heavy Use class was associated with more SAM consequences. As might be expected, the Light Alcohol-Heavy Cannabis use class endorsed the fewest alcohol consequences, whereas the Heavy Alcohol-Light Cannabis class endorsed the fewest cannabis consequences. Experience of alcohol related consequences at follow-up was similar between the Heavy Use and Heavy Alcohol-Light Cannabis classes, suggesting that heavier alcohol involvement (e.g., high BAC, HED) was driving the association between substance use behaviors and a broad assessment of consequences. As well, cannabis consequences were similar between the Heavy Use and the Light Alcohol-Heavy Cannabis classes, suggesting that greater quantity and frequency of cannabis use was most indicative of cannabis consequences at follow-up. Taken together, these findings demonstrate that along with increased SAM use, substance-specific behaviors (e.g., alcohol quantity, cannabis quantity) are important in understanding risk of incurring alcohol, cannabis, and SAM consequences. Importantly, risk of SAM consequences appears to be specifically tied to frequent SAM use or heavy use of both substances, as heavy use of alcohol-alone or cannabis-alone was not associated with increased risk of SAM consequences at follow-up. This pattern is somewhat discrepant from work examining event-level SAM use and subsequent consequences that found heavy alcohol use during a SAM occasion was associated with increased SAM consequences (Metrik et al., 2016; Sokolovsky et al., 2020) and that this pattern held regardless of event-level cannabis use (Mallett et al., 2019). Understanding broader patterns of use could serve to inform just-in-time interventions. For example, if an individual engages in a pattern of use closely aligned with the Light Alcohol-Heavy Cannabis class (i.e., infrequent, low quantity of alcohol use but frequent, higher quantity of cannabis use, multiple forms and moderate SAM use) reports an increase in alcohol consumption, that could serve as a catalyst for engaging the individual in brief intervention.

An important aspect of the present work was the use of daily data to predict experiences of consequences at 3-month follow-up rather than predicting event-specific consequences. Individuals may report consequences differently depending on timeframe or context. For example, there may be consequences that individuals do not attribute to a particular use event (e.g., changes in cognitive or academic performance) but that they report experiencing when reflecting on a broader timeframe. Similarly, individuals may be more accurate at reporting more acute events at the event- or day-level (e.g., affect changes) compared to broadened timeframes. As such, future work should aim to parse out how event-level alcohol and cannabis use on SAM occasions relate to acute consequences compared to aggregate patterns. Additionally, use of cognitive interviews could provide nuanced information on how individuals interpret, subjectively evaluate, and respond to consequences items at differing time intervals (e.g., event-level v. 3-months) and for specific substances (e.g., Freeman et al., 2022; Merrill et al., 2020; Patrick & Maggs, 2011).

Future work should also examine how class membership relates to event-level consequences and how these relations are impacted by contextual variables. For example, Jackson et al. (2021) found that event-level motives, presence of peers, and peer use resulted in different rates of alcohol, cannabis, and SAM use. As such, understanding under what contexts individuals in these classes are at increased risk of adverse outcomes could aid in refinement of intervention and prevention efforts. In addition to contextual variables, drinker identity and cannabis user identity may also be indicative of alcohol, cannabis, and SAM patterns among those

engaging in co-use. Extant work highlights that drinker identity (i.e., how closely one views drinking as part of their self-concept) is associated with increased alcohol use and subsequent consequences (Lindgren et al., 2016a; Lindgren et al., 2016b), and increased cannabis user identity is associated with more cannabis problems (Blevins et al., 2018). Understanding the extent to which individuals view themselves as a "drinker," "cannabis user," or both could aid in understanding distinct patterns of alcohol, cannabis, and SAM use in the context of co-use. Further, identifying more strongly as a user of alcohol or cannabis could have implications for SAM ordering effects (e.g., someone with a high alcohol user identity and low cannabis user identity may be more likely to initiate SAM with alcohol).

In addition to frequency and quantity of use, the present work examined differences in standard deviations in daily quantity of alcohol and cannabis use (i.e., lower standard deviations are indicative of more consistent quantities of use). Interestingly, results found that heavy use was associated with greater standard deviations in use compared to light use; for example, the Heavy Use and Heavy Alcohol-Light Cannabis classes had greater standard deviations in typical number of drinks than the Light Alcohol-Heavy Cannabis class. Though this finding needs to be replicated, it indicates that variability in use may be a unique factor associated with subsequent outcomes. For example, individuals who drink less frequently and in lower quantities may be intentionally limiting their drinks or may experience the physiological effects of alcohol at lower quantities than those drinking more frequently. However, as an individual engages in more frequent or heavier use, they may not be as conscious of their number of drinks or may need to drink higher quantities to experience the effects of alcohol. Another potential explanation for this pattern could be that individuals may continue to use until a desired effect is achieved (e.g., feeling intoxicated; coping with stress) and that those using a substance more frequently may have a wider range of motives for use, and thus, have greater variability in their quantities (Stevens et al., 2021). It may also be that more frequent alcohol users have greater variability because they drink on weekdays and weekends, which results in more inconsistency in quantity, whereas primary cannabis users may drink more exclusively on weekends mostly in the same quantities. Finally, heavier users have a higher range of drinking and thus mathematically deviations can be greater.

The classes derived in the present work appear largely driven by heavy single-substance use (i.e., greater quantity and frequency) or heavy alcohol, cannabis, and SAM use. This is somewhat discrepant from previous class models of alcohol, cannabis, and SAM use (Patrick et al., 2018; Lanza et al., 2022). In their analyses, Lanza et al., (2022) found a five-class solution with classes driven by the frequency of SAM use (i.e., frequent, moderate, and infrequent), order of initiation on SAM occasions, and presence of heavy drinking. Cannabis use behavior was largely unrelated to class estimation in that analysis. This discrepancy could be due in large part to the inclusion of consequences in the class estimation rather than use of consequences as an outcome variable (as in the present study), particularly given the tendency to endorse fewer cannabis consequences or to attribute SAM consequences predominately to alcohol (Jackson et al., 2021).

Beyond elucidating unique SAM profiles and risk patterns, the present findings inform prevention and intervention considerations for alcohol and cannabis co-use. Notably, heavy use of a single substance was indicative of consequences for that substance, but risk was not increased between substances, suggesting some specificity of risk. As such, tailoring prevention and interventions for emerging adults engaging in SAM use should take into consideration whether the individual has a primary substance of choice, and if so, modify content to emphasize the primary substance. For example, interventions aimed at increasing use of protective behavioral strategies targeting the primary substance(s) could be effective in reducing negative consequences of use (e.g., Riggs et al., 2018), particularly when delivered in potentially high-risk use contexts (e.g., university game days, Edwards et al., 2020). There is limited work examining specific interventions aimed at SAM use and extant work has found that alcohol interventions do not tend to influence cannabis use, further highlighting a need for increased work evaluating SAM and cannabis-focused interventions for emerging adults that co-use substances (see Lee et al., 2022 for review). For

individuals with any co-use, it is important that both substances are addressed in the context of clinical interventions to mitigate risks (Metrik et al., 2018).

Limitations and Future Directions

The strengths of this study include the use of a multisite sample responding to multiple daily surveys and robust analyses that facilitated investigating person-level indicators of substance use patterns aggregated from within-person behavior. Despite the strengths of this work, several limitations exist. First, analyses focused exclusively on alcohol and cannabis use and did not control for the use of other substances (e.g., nicotine products) as class indicators. Work by Mallet and colleagues (2017) suggests that using alcohol with any second substance (e.g., cannabis, nicotine, cocaine) results in increased risk of negative outcomes and as such, future work should aim to determine how relations between consequences and alcohol and cannabis co-use patterns are impacted by use of additional substances. Further, though daily surveys are associated with increased accuracy of alcohol and cannabis use self-report (Freeman et al., 2022), individuals tend to overestimate their quantity of cannabis use and underestimate their alcohol use quantity (Prince et al., 2018; Shultz et al., 2017). As such, future works should aim to replicate these findings using multimethod assessment (e.g., wearable measures, direct observation).

Follow-up consequences were asked about the preceding three months and, thus, there was some overlap with the period of the daily survey assessment. At follow-up, alcohol, cannabis, and SAM consequences were presented as dichotomous items. As such, this work determined relations between patterns of co-use and total number of types of consequences (e.g., blackout, hangover), but not frequency or type of consequences. It could be that some individuals experience a broader range of consequences but infrequently, whereas others may experience a more restricted range of consequences but more frequently. Further, differentiating between acute (e.g., impaired coordination) and less acute (e.g., academic difficulties) consequences of use is an important consideration for future research on co-use patterns. Lastly, the sample included college students who were predominately White and may not be representative of a more diverse young adult population.

Conclusion

Among those reporting SAM use, there are distinct patterns of cannabis, alcohol, and SAM use that differentially relate to negative substance use consequences at follow-up. Consistent with prior work, increased SAM use in conjunction with heavy, frequent alcohol and cannabis use is associated with increased SAM consequences. Importantly, heavy use of a single substance is indicative of consequences for that substance but is not associated with increased risk of SAM consequences. As such, among individuals who endorse SAM use, but demonstrate a pattern of primarily using cannabis or primarily using alcohol, intervention and prevention efforts may be most successful by targeting the primary substance rather than both substances in tandem or simultaneous use. Further, given that greater standard deviations in quantity of use varied between classes, exploring how use of individual substances vary between events and days could serve as an important marker for just-in-time interventions.

REFERENCES

Asparouhov, T., & Muthén, B. (2021). Auxiliary variables in mixture modeling: Using the BCH method in Mplus to estimate a distal outcome model and an arbitrary secondary model. *Mplus Web Notes*, *21*(2), 1-22.

Blevins, C. E., Abrantes, A. M., Anderson, B. J., Caviness, C. M., Herman, D. S., & Stein, M. D. (2018). Identity as a cannabis user is related to problematic patterns of consumption among emerging adults. *Addictive Behaviors*, *79*, 138-143. https://doi.org/10.1016/j.addbeh.2017.12.021

Briere, F. N., Fallu, J. S., Descheneaux, A., & Janosz, M. (2011). Predictors and consequences of simultaneous alcohol and cannabis use in adolescents. *Addictive Behaviors*, *36*(7), 785-788. https://doi.org/10.1016/j.addbeh.2011.02.012

Bolck, A., Croon, M., & Hagenaars, J. (2004). Estimating latent structure models with categorical variables: One-step versus three-

step estimators. *Political Analysis*, *12*(1), 3-27. doi:10.1093/pan/mph001

Cummings, C., Beard, C., Habarth, J. M., Weaver, C., & Haas, A. (2019). Is the sum greater than its parts? Variations in substance-related consequences by conjoint alcohol-marijuana use patterns. *Journal of Psychoactive Drugs*, *51*(4), 351-359. doi:10.1080/02791072.2019.1599473

Downey, L. A., King, R., Papafotiou, K., Swann, P., Ogden, E., Boorman, M., & Stough, C. (2013). The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. *Accident Analysis & Prevention*, *50*, 879-886. https://doi.org/10.1016/j.aap.2012.07.016

Edwards, S. M., Tuliao, A. P., Kennedy, J. L., & McChargue, D. E. (2020). Weekend text messages increase protective behavioral strategies and reduce harm among college drinkers. *Journal of Technology in Behavioral Science*, *5*(4), 395-401.

Freeman, L. K., Haney, A. M., Griffin, S. A., Fleming, M. N., Vebares, T. J., Motschman, C. A., & Trull, T. J. (2022). Agreement between momentary and retrospective reports of cannabis use and alcohol use: Comparison of ecological momentary assessment and timeline followback indices. *Psychology of Addictive Behaviors*. https://doi.org/10.1007/s41347-020-00149-4

Gunn, R. L., Sokolovsky, A., Stevens, A. K., Metrik, J., White, H., & Jackson, K. (2021). Ordering in alcohol and cannabis co-use: Impact on daily consumption and consequences. *Drug and Alcohol Dependence*, *218*, 108339. https://doi.org/10.1016/j.drugalcdep.2020.108339

Jackson, K. M., Sokolovsky, A. W., Gunn, R. L., & White, H. R. (2020). Consequences of alcohol and marijuana use among college students: Prevalence rates and attributions to substance-specific versus simultaneous use. *Psychology of Addictive Behaviors*, *34*(2), 370-381. https://doi.org/10.1037/adb0000545

Jackson, K. M., Stevens, A. K., Sokolovsky, A. W., Hayes, K. L., & White, H. R. (2021). Real-world simultaneous alcohol and cannabis use: An ecological study of situational motives and social and physical contexts. *Psychology of Addictive Behaviors*, *35*(6), 698-711. https://doi.org/10.1037/adb0000765

Kahler, C. W., Strong, D. R., & Read, J. P. (2005). Toward efficient and comprehensive measurement of the alcohol problems continuum in college students: The Brief Young Adult Alcohol Consequences Questionnaire. *Alcoholism: Clinical and Experimental Research*, *29*(7), 1180-1189. https://doi.org/10.1097/01.ALC.0000171940.95813.A5

Karoly, H. C., Conner, B. T., & Prince, M. A. (2022). Associations between alcohol and cannabis use order, frequency, quantity, and consequences in a college sample of individuals who co-use alcohol and cannabis. *The American Journal on Addictions,* 1-8. doi:10.1111/ajad.13370

Lanza, S. T., Sokolovsky, A. W., Linden-Carmichael, A. N., White, H. R., & Jackson, K. M. (2022). Understanding heterogeneity among simultaneous alcohol and marijuana users: latent classes derived from daily diary data. *Journal of Studies on Alcohol and Drugs*, *83*(3), 358-363. https://doi.org/10.15288/jsad.2022.83.358

Laursen, B., & Hoff, E. (2006). Person-centered and variable-centered approaches to longitudinal data. *Merrill-Palmer Quarterly*, *52*(3), 377–389. http://www.jstor.org/stable/23096200

Lee, C. M., Calhoun, B. H., Abdallah, D. A., Blayney, J. A., Schultz, N. R., Brunner, M., & Patrick, M. E. (2022). Simultaneous alcohol and marijuana use among young adults: A scoping review of prevalence, patterns, psychosocial correlates, and consequences. *Alcohol Research*. https://doi.org/10.35946/arcr.v42.1.08

Lee, C. M., Patrick, M. E., Fleming, C. B., Cadigan, J. M., Abdallah, D. A., Fairlie, A. M., & Larimer, M. E. (2020). 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. *Alcoholism, Clinical and Experimental Research, 44*(3), 689–696. https://doi.org/10.1111/acer.14279

Linden-Carmichael, A. N., Van Doren, N., Masters, L. D., & Lanza, S. T. (2020). Simultaneous alcohol and marijuana use in

daily life: Implications for level of use, subjective intoxication, and positive and negative consequences. *Psychology of Addictive Behaviors, 34*(3), 447–453. https:// doi.org/10.1037/adb0000556

Lindgren, K. P., Neighbors, C., Teachman, B. A., Baldwin, S. A., Norris, J., Kaysen, D., ... & Wiers, R. W. (2016). Implicit alcohol associations, especially drinking identity, predict drinking over time. *Health Psychology*, *35*(8), 908. https://doi.org/10.1037/hea0000396

Lindgren, K. P., Ramirez, J. J., Olin, C. C., & Neighbors, C. (2016). Not the same old thing: Establishing the unique contribution of drinking identity as a predictor of alcohol consumption and problems over time. *Psychology of Addictive Behaviors*, *30*(6), 659 – 671. https://doi.org/10.1037/adb0000195

Lipperman-Kreda, S., Gruenewald, P. J., Grube, J. W., & Bersamin, M. (2017). Adolescents, alcohol, and marijuana: Context characteristics and problems associated with simultaneous use. *Drug and Alcohol Dependence, 179*, 55– 60. http://dx.doi.org/10.1016/j.drugalcdep.2017.06 .023

Looby, A., Prince, M. A., Villarosa-Hurlocker, M. C., Conner, B. T., Schepis, T. S., & Bravo, A. J. (2021). Young adult use, dual use, and simultaneous use of alcohol and marijuana: An examination of differences across use status on marijuana use context, rates, and consequences. *Psychology of Addictive Behaviors*. *35*(6), 682-690. https://doi.org/10.1037/adb0000742

Mallett, K. A., Turrisi, R., Hultgren, B. A., Sell, N., Reavy, R., & Cleveland, M. (2017). When alcohol is only part of the problem: An event-level analysis of negative consequences related to alcohol and other substance use. *Psychology of Addictive Behaviors, 31*, 307–314. http:// dx.doi.org/10.1037/adb0000260

Mallett, K. A., Turrisi, R., Trager, B. M., Sell, N., & Linden-Carmichael, A. N. (2019). An examination of consequences among college student drinkers on occasions involving alcohol-only, marijuana-only, or combined alcohol and marijuana use. *Psychology of Addictive Behaviors, 33*, 331–336. http://dx.doi.org/10.1037/adb0000458

McCabe, S. E., Arterberry, B. J., Dickinson, K., Evans-Polce, R. J., Ford, J. A., Ryan, J. E., & Schepis, T. S. (2021). Assessment of changes in alcohol and marijuana abstinence, co-use, and use disorders among us young adults from 2002 to 2018. *JAMA Pediatrics, 175*(1), 64–72. https:// doi.org/10.1001/jamapediatrics.2020.3352

Merrill, J. E., Fan, P., Wray, T. B., & Miranda Jr, R. (2020). Assessment of alcohol use and consequences: Comparison of data collected via timeline followback interview and daily reports. *Journal of studies on alcohol and drugs*, *81*(2), 212-219. https://doi.org/10.15288/jsad.2020.81.212

Miech, R. A., Johnston, L. D., O'Malley, P. M., Bachman, J. G., Schulenberg, J. E., & Patrick, M. E. (2018). Monitoring the Future national survey results on drug use, 1975–2017: Volume I, secondary school students. Institute for Social Research

Metrik, J., Caswell, A. J., Magill, M., Monti, P. M., & Kahler, C. W. (2016). Sexual risk behavior and heavy drinking among weekly marijuana users. *Journal of Studies on Alcohol and Drugs, 77*, 104 –112. http://dx.doi.org/10.15288/jsad.2016.77.104

Metrik, J., Gunn, R. L., Jackson, K. M., Sokolovsky, A. W., & Borsari, B. (2018). Daily patterns of marijuana and alcohol co-use among individuals with alcohol and cannabis use disorders. *Alcoholism: Clinical and Experimental Research, 42*, 1096–1104. http://dx.doi.org/10.1111/acer .13639

Muthén, L. K. and Muthén, B.O. (1998-2017). *Mplus user's guide*. Eighth Edition. Los Angeles, CA: Muthén & Muthén.

National Institute on Alcohol Abuse and Alcoholism. (2022, November). *Understanding the dangers of alcohol overdose*. National Institute on Alcohol Abuse and Alcoholism. https://www.niaaa.nih.gov/publications/broch ures-and-fact-sheets/understanding-dangers-of-alcohol-overdose.

O'Donnell, M. L., Schaefer, I., Varker, T., Kartal, D., Forbes, D., Bryant, R. A., ... & Steel, Z. (2017). A systematic review of person-centered approaches to investigating patterns of trauma exposure. *Clinical Psychology Review*, *57*, 208-225. https://doi.org/10.1016/j.cpr.2017.08.009

Patrick, M. E., & Lee, C. (2018). Cross-faded: Young adults' language of being simultaneously drunk and high. *Cannabis, 1,* 60–65. http://dx.doi .org/10.26828/cannabis.2018.02.006

Patrick, M. E., Kloska, D. D., Terry-McElrath, Y. M., Lee, C. M., O'Malley, P. M., & Johnston, L. D. (2018). Patterns of simultaneous and concurrent alcohol and marijuana use among adolescents. *The American Journal of Drug and Alcohol Abuse, 44(*4), 441–451. https://doi.org/10.1080/00952990.2017.1402335

Patrick, M. E., & Maggs, J. L. (2011). College students' evaluations of alcohol consequences as positive and negative. *Addictive behaviors*, *36*(12), 1148-1153. https://doi.org/10.1016/j.addbeh.2011.07.011

Patrick, M. E., Terry-McElrath, Y. M., Lee, C. M., & Schulenberg, J. E. (2019). Simultaneous alcohol and marijuana use among underage young adults in the United States. *Addictive Behaviors, 88*, 77–81. https://doi.org/ 10.1016/j.addbeh.2018.08.015

Prince, M. A., Conner, B. T., & Pearson, M. R. (2018). Quantifying cannabis: A field study of marijuana quantity estimation. *Psychology of Addictive Behaviors*, *32*(4), 426-433. https://doi.org/10.1037/adb0000370

Riggs, N. R., Conner, B. T., Parnes, J. E., Prince, M. A., Shillington, A. M., & George, M. W. (2018). Marijuana eCHECKUPTO GO: Effects of a personalized feedback plus protective behavioral strategies intervention for heavy marijuana-using college students. *Drug and Alcohol Dependence*, *190*, 13-19. https://doi.org/10.1016/j.drugalcdep.2018.05.020

Schultz, N. R., Kohn, C. S., Schmerbauch, M., & Correia, C. J. (2017). A systematic review of the free-pour assessment: Implications for research, assessment and intervention. *Experimental and Clinical Psychopharmacology*, *25*(3), 125-140. https://doi.org/10.1037/pha0000120

Shanahan, L., Copeland, W. E., Worthman, C. M., Erkanli, A., Angold, A., & Costello, E. J. (2013). Sex-differentiated changes in C-reactive protein from ages 9 to 21: the contributions of BMI and physical/sexual maturation. *Psychoneuroendocrinology*, *38*(10), 2209-2217. https://doi.org/10.1016/j.psyneuen.2013.04.010

Simons, J. S., Dvorak, R. D., Merrill, J. E., & Read, J. P. (2012). Dimensions and severity of marijuana consequences: Development and validation of the Marijuana Consequences Questionnaire (MACQ). *Addictive Behaviors*, *37*(5), 613-621. https://doi.org/10.1016/j.addbeh.2012.01.008

Sokolovsky, A. W., Gunn, R. L., Micalizzi, L., White, H. R., & Jackson, K. M. (2020). Alcohol and marijuana co-use: Consequences, subjective intoxication, and the operationalization of simultaneous use. *Drug and Alcohol Dependence*, *212*, 107986. https://doi.org/10.1016/j.drugalcdep .2020.107986

Stevens, A. K., Drohan, M. M., Boyle, H. K., White, H. R., & Jackson, K. M. (2021). More reasons, more use and problems? Examining the influence of number of motives on consumption and consequences across alcohol-only, cannabis-only, and simultaneous-use Days. *Journal of Studies on Alcohol and Drugs*, *82*(6), 782-791.

Stevens, A. K., Sokolovsky, A. W., Treloar Padovano, H., White, H. R., & Jackson, K. M. (2020). Heaviness of alcohol use, alcohol problems, and subjective intoxication predict discrepant drinking reports in daily life. *Alcoholism: Clinical and Experimental Research*, *44*(7), 1468-1478. https://doi.org/10.15288/jsad.2021.82.782

Subbaraman, M. S., & Kerr, W. C. (2015). Simultaneous versus concurrent use of alcohol and cannabis in the National Alcohol Survey. *Alcoholism, Clinical and Experimental Research, 39*, 872– 879. http://dx.doi.org/10 .1111/acer.12698

Terry-McElrath, Y. M., & Patrick, M. E. (2018). Simultaneous alcohol and marijuana use among young adult drinkers: Age-specific changes in prevalence from 1977 to 2016. *Alcoholism, Clinical and Experimental Research*, 42(11), 2224–2233. https://doi.org/10.1111/acer.13879

Thompson, K., Holley, M., Sturgess, C., & Leadbeater, B. (2021). Co-use of alcohol and cannabis: longitudinal associations with mental health outcomes in young adulthood. *International Journal of Environmental Research and Public*

Health, *18*(7), 3652-3561. https://doi.org/10.3390/ijerph18073652

White, H. R., Kilmer, J. R., Fossos-Wong, N., Hayes, K., Sokolovsky, A. W., & Jackson, K. M. (2019). Simultaneous alcohol and marijuana use among college students: Patterns, correlates, norms, and consequences. *Alcoholism, Clinical and Experimental Research, 43*, 1545– 1555. http://dx.doi.org/10.1111/acer.14072

Yurasek, A. M., Aston, E. R., & Metrik, J. (2017). Co-use of alcohol and cannabis: A review. *Current Addiction Reports, 4*, 184 –193. http://dx .doi.org/10.1007/s40429-017-0149-8

Funding and Acknowledgements: The writing of this paper was supported in part by NIDA Grants R01DA040880 (MPIs: Jackson, White) and K08DA048137 (PI: Sokolovsky), and NIAAA Grant K08AA027551 (PI: Gunn). Training support was provided to Holly Boyle (NIAAA T32AA007459, PI: Miranda). Points of view in this document are those of the authors and do not necessarily represent the official position or policies of the National Institutes of Health. The funding sources had no role in the analysis or interpretation of the data, the preparation of this manuscript, or the decision to submit the manuscript for publication. The authors declare no conflicts of interest.