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Does cannabis use predict more severe types of alcohol consequences? Longitudinal associations in a three-year study of college students

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Abstract

Background: Prior research shows that negative drinking outcomes among young adults may be exacerbated by cannabis use. However, to date there have been few longitudinal studies of associations between cannabis use and negative alcohol-related consequences. This study examined longitudinal within-person associations between cannabis use and several domains of negative alcohol consequences among young adults and explored the moderating role of sex.

Method: We analyzed data from N=997 students assessed four times per year over the first three years of university. At each time point, participants completed measures of past month cannabis use frequency, typical weekly number of drinks, and eight domains of negative alcohol consequences. Longitudinal associations were examined in multilevel models.

Results: Within-person changes in frequency of cannabis use were not uniquely associated with changes in total alcohol consequences aggregated across several alcohol consequence domains. However, when examining alcohol consequence domains separately, within-person increases in cannabis use frequency were specifically associated with increases in some (but not all) of the more severe types of alcohol consequences, including risky behaviours, poor self-care, and alcohol dependence symptoms. No support was observed for the moderating role of sex in the longitudinal within-person associations between cannabis use and alcohol consequence domains.

Conclusions: Findings suggest that within-person changes in cannabis use frequency among young adults are associated with corresponding changes in some domains of alcohol consequences (but not others) when examined over the course of several years. Results may inform targeted harm reduction interventions for young adult drinkers who use cannabis, although future research is needed to clarify the mechanisms of the observed associations.

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Keywords

Marijuana; alcohol problems; polysubstance; prospective; emerging adult

Introduction

Although alcohol is still the most widely used psychoactive substance, the prevalence and frequency of cannabis use has been increasing among adults in the U.S. since 2007 (Mauro et al., 2018; Substance Abuse and Mental Health Services Administration, 2017). Young adults have the highest rates of both cannabis use and alcohol use, with past-month prevalence estimates among 18–25 year olds of 20.8% and 57.1%, respectively (Substance Abuse and Mental Health Services Administration, 2017). Further, many young adults are "co-users" of alcohol and cannabis, a broad term that refers to individuals who use both substances during the same period of time, although not necessarily on the same occasion (Yurasek et al., 2017, Gunn et al., 2018). Indeed, 20–30% of young adult drinkers are co-users of alcohol and cannabis (Midanik et al., 2007, Patrick et al., 2019, Subbaraman and Kerr, 2015), and recent data suggest that this rate has generally increased among young adults since the 1990s (Terry-McElrath and Patrick, 2018).

Epidemiological surveys show that alcohol and cannabis co-users have an elevated risk for negative outcomes when compared to those who use alcohol only, including social and occupational problems, harms to self and others, impaired driving, mood-related symptoms, and symptoms of alcohol use disorder (Green et al., 2019, Midanik et al., 2007, Subbaraman and Kerr, 2015). Similar findings have been reported in samples of young adults (e.g., Arterberry et al., 2017, Gunn et al., 2018, Haas et al., 2015, Linden-Carmichael et al., 2019, Shillington and Clapp, 2001). Further, among young adults, the vast majority of co-users report simultaneous alcohol and cannabis use (i.e., using both substances on the same occasion; Subbaraman and Kerr, 2015), a behaviour that appears to be associated with greater risk for harms than using the two substances on separate occasions (Brière et al., 2011, Egan et al., 2019, Jackson et al., 2020, Subbaraman and Kerr, 2015). Importantly, research suggests that the likelihood and severity of negative drinking outcomes is increased by cannabis use even when controlling for the level of alcohol consumed (Gunn et al., 2018, Linden-Carmichael et al., 2019, Midanik et al., 2007, Subbaraman and Kerr, 2015). Accordingly, there has been growing interest in understanding the role of cannabis use in alcohol-related outcomes.

However, much of the prior research on the link between cannabis use and alcohol-related harms is limited to cross-sectional data, making it difficult to isolate the dynamic, within-person influence of cannabis use on alcohol-related consequences from between-person individual differences that might account for these associations. This is important because the mechanisms explaining the association between cannabis use and alcohol consequences may differ across within-person and between-person levels. For example, at the within-person level, cannabis and alcohol may have additive effects on cognitive and behavioural impairment (e.g., Ramaekers et al., 2011, Winward et al., 2014; for review, see Yurasek et al., 2017), such that a *within-person* increase in cannabis use during a given period in time

would be expected to coincide with exacerbation of alcohol-related consequences during the same time period. Alternatively, at the between-person level, personality traits or other individual-level factors that are correlated with cannabis use (e.g., impulsivity, demographics) may explain the link between cannabis use and alcohol consequences. In this case, fluctuations over time in an individual's level of cannabis use may have little direct impact on the harms they experience from alcohol.

In contrast to the cross-sectional studies showing between-person differences in alcohol-related consequences between co-users and alcohol-only users, the handful of existing studies of daily-level within-person associations have not found strong evidence that drinkers experience more negative alcohol consequences on days that they use cannabis and alcohol vs. days that they use alcohol alone after controlling for alcohol consumption (Lipperman-Kreda et al., 2017, Mallett et al., 2019, Merrill et al., 2019; but, see Linden-Carmichael et al., 2020, for one exception). However, one important caveat is that these types of daily diary and ecological momentary assessment (EMA) studies are best suited for examining *acute* consequences that occur at the daily-level (e.g., blackouts, hangovers) and tend to capture within-person predictors of these consequences over brief time periods (e.g., a period of a few weeks). Longer-term longitudinal studies are required to examine how within-person fluctuations in cannabis use over the course of months or years may be related to changes in alcohol consequences that are more chronic or accumulate over longer timeframes (e.g., academic problems, dependence symptoms, poor self-care). To date, there have been very few such within-person longitudinal analyses. In one example, Gunn et al. (2018) examined the association between weekly cannabis use and weekly alcohol consequences assessed with biweekly surveys administered over the first 2 years of college. These investigators observed a significant within-person association over time between greater frequency of cannabis use and both greater total positive consequences and greater total negative alcohol consequences, controlling for alcohol use. This suggests that cannabis use does appear to have a within-person effect on alcohol consequences over longer time periods that cannot be fully accounted for by differences in levels of alcohol use.

The Gunn et al. (2018) paper represents an important advancement in longitudinal research on the link between cannabis use and alcohol consequences. Yet, this study examined negative consequences only in aggregate, and did not examine specific types of negative consequences. Negative alcohol consequences among college students span a wide range of domains that vary in prevalence and severity (Perkins, 2002, White and Hingson, 2013). For example, previous research shows that poor self-care, academic/occupational problems, and alcohol dependence symptoms are less likely to be endorsed among college student drinkers than social consequences, blackouts, and impaired control over alcohol (Read et al., 2006, Read et al., 2016), which suggests that the former reflect a greater level of alcohol problem severity in this population (see Kahler et al., 2005). The utility of distinguishing among different domains of negative alcohol consequences has been demonstrated in several studies, showing that different domains are differentially associated with patterns of drinking and other relevant variables in both cross-sectional and prospective analyses (Merrill and Read, 2010, Merrill et al., 2014, Read et al., 2007, Read et al., 2013a). Further, a recent cross-sectional study by Jackson and colleagues (2020) found that young adults who used alcohol and cannabis simultaneously differed from those who used alcohol alone on several

alcohol consequence domains, but larger differences were observed for driving-related, blackout, and cognitive consequences relative to other consequence types. However, the existing longitudinal studies of the link between cannabis and alcohol consequences have tended to aggregate across different types of consequences, perhaps obscuring important differential prospective associations with unique domains of negative alcohol consequences. This is an important gap in the literature, as the ways in which cannabis use may exacerbate particular types of harmful drinking outcomes over time is still unclear.

Conceptually, if cannabis use increases risk for alcohol-related consequences due to additive effects on cognitive or behavioural impairment from alcohol, perhaps increased cannabis use over time will be linked with increases in more severe consequence domains that are more likely to emerge at higher levels of impairment. For example, less common and more severe negative consequences such as poor self-care, academic/occupational problems, and alcohol dependence symptoms may be more likely to result from higher levels of alcohol-related impairment. So, increased cannabis use may have a unique impact on the likelihood of these more severe types of alcohol consequences by adding to the level of impairment that drinkers experience. Though Mallett et al. (2019) made a distinction between social and physical consequences in their study (with similar findings reported across these domains), they focused on daily-level associations between cannabis and alcohol outcomes over brief, discrete periods of time (i.e., weekend days across 6 different weekends). There are no longitudinal studies that examine the within-person link between changes in cannabis use and unique negative alcohol consequence domains over longer time frames (e.g., several years). Such studies are needed, as they could inform interventions for young adult drinkers. For example, research shows that young adults evaluate some types of alcohol consequences more negatively than others (e.g., Mallett et al., 2008, Merrill et al., 2013), and a focus on the specific consequences that are most salient to drinkers appears to be important for motivating changes in drinking behaviour (Barnett et al., 2015, Merrill et al., 2019). Accordingly, if cannabis use is associated with increased risk for relatively severe alcohol consequences, these specific consequences could be targeted in feedback interventions tailored for young adult drinkers who use cannabis.

Aims and Hypotheses

The goal of this study was to examine the longitudinal within-person associations between changes in cannabis use and unique domains of negative alcohol consequences. We used data from a cohort study of college students who completed surveys assessing past month alcohol use, cannabis use, and alcohol consequences four times per year over the first three years of college. We hypothesized that within-person fluctuations in the frequency of cannabis use would predict corresponding changes in total negative alcohol consequences over and above the variance accounted for by concurrent changes in alcohol use. We also hypothesized that the within-person association between changes in cannabis use and changes in alcohol consequences would be stronger for more vs. less severe alcohol consequence types.

Method

Participants and Procedures

The current study involved a secondary analysis of data from a multisite study focused on trauma and drinking among university students. Primary outcomes regarding the relationship between trauma, PTSD and substance use have been previously published (Read et al., 2012, Read et al., 2013b), and for the current study we focused only on cannabis use and alcohol use and problems measures. Recruitment procedures are described in detail elsewhere (Read et al., 2011). Briefly, freshman from two state universities (one in the Northeast U.S. and one in the Southeast U.S.) were invited to complete a brief screening survey (N = 5,885). A total of 3,391 students completed this screening, of which 1234 (n=649 with trauma/PTSD symptoms and n=585 demographically matched students without trauma/PTSD) were targeted for longitudinal follow up. The final sample consisted of 997 students who completed the baseline survey (81% response rate) in September of their first year in college. We used data from the first 3 years of the study (during which the entire cohort was followed), which included assessments in September, December, February, and April of each year (12 total time points).[1]

The analytic sample (N = 997) was approximately 65% female (n = 649) with a mean age of 18.11 (SD = 0.45). The ethnic composition was 72.8% White (n = 723), 11.4% Asian (n = 113), 9.1% Black (n = 90), 3.3% Hispanic/Latino (n = 33), 3.1% Biracial (n = 31), 0.2% American Indian/Alaskan Native (n = 2), and 0.1% Hawaiian/Pacific Islander (n = 1). Median family income was in the $61,000 to $80,000 range. At time 1, 46.64% (n = 455) lived on campus in a residence hall or campus apartment, whereas only 13.34% (n = 133) lived on campus by time 12. Affiliation with Greek organizations ranged from 1.24% (n = 12) at time 1 to 10.33% (n = 103) at time 12.

Measures

Alcohol Use.—At each time point, participants completed the Daily Drinking Questionnaire (DDQ; Collins et al., 1985) to report their typical weekly alcohol consumption during the past month. Participants were asked to report on the number of standard drinks typically consumed on each day of the week. We provided a standard drink chart to participants to improve reporting accuracy. Responses were summed across days to derive an estimate of the total number of drinks typically consumed in a week over the past month.

Alcohol-related consequences.—Participants completed the Young Adult Alcohol Consequences Questionnaire (YAACQ; Read et al., 2006) at each time point, which assessed alcohol-related consequences during the past 30 days. The YAACQ is a 48-item self-report measure that assesses eight domains of alcohol-related consequences. The YAACQ was designed to assess consequences across the entire severity spectrum, and statistical modeling has shown that YAACQ items provide good coverage of both lower severity consequences

[1]Although Year 1 also included assessments in October and November, these were not analyzed in the current study as these assessment time points were dropped from years 2 and years 3. This allowed us to maintain consistency in the time of year corresponding to each assessment across the three years in the analysis.

(i.e., items that are more commonly endorsed) and higher severity consequences (i.e., items that are less commonly endorsed; Kahler et al., 2005). Based on the proportion of items endorsed for each subscale in the original validation study (Read et al., 2006), the YAACQ domains can be ordered from most to least frequently endorsed (reflecting increasing level of severity): blackout/hangover consequences (7 items, e.g., "I have awakened the day after drinking and found I could not remember a part of the evening before"), social-interpersonal consequences (6 items, e.g., "while drinking, I have said or done embarrassing things"), impaired control (6 items, e.g., "I often have found it difficult to limit how much I drink"), risky behaviors (8 items, e.g., "I have driven a car when I knew I had too much to drink to drive"), academic/occupational consequences (5 items, e.g., "I have gotten into trouble at work or school because of drinking"), self-perception consequences (4 items, e.g. "I have felt guilty about my drinking"), self-care consequences (8 items, e.g., "Because of my drinking, I have not eaten properly"), and physical dependence (4 items, e.g., "I have felt anxious, agitated, or restless after stopping or cutting down on drinking").

Participants indicated whether they experienced each consequence in the past month (Yes/No). Subscales were scored by summing the number of consequences endorsed on each scale. Further, as all scales load on a single higher-order factor (Read et al., 2006), we also summed all items to derive a total consequences score at each time point (observed range 0–48). Given that items are dichotomous, internal reliabilities were calculated using tetrachoric correlations (Read et al., 2006). The total scale exhibited good internal reliability at each time point (range 0.98 to 0.99), as did each subscale: social-interpersonal (range 0.91 to 0.95), impaired control (range 0.91 to 0.95), self-perception (range 0. 91 to 0.96), self-care (range 0.93 to 0.96), risky behaviors (range 0.90 to 0.94), academic/occupational (range 0.90 to 0.96), physical dependence (range 0.84 to 0.92), and blackout/hangover (range 0.92 to 0.97).

Cannabis use.—Frequency of cannabis use during the past 30 days was assessed with an item that read, "In the past month, how often have you used cannabis for non-medicinal purposes?" Responses were scored on a 7-point ordinal scale ranging from 0 ("*Never in the past month*") to 6 ("*Everyday in the past month*").

Data Analytic Approach

Multilevel modeling was conducted using Mplus v.7 (Muthén and Muthén, 2012) to examine longitudinal associations between cannabis use and alcohol consequences. Each participant contributed up to 12 observations to the analysis (4 time points per year for 3 years). The analyses used all available data, and participants missing data at one or more time points were retained in the analysis with the use of the maximum likelihood estimator. Rates of missing data at each time point ranged from 6.32% to 15.45%. Participants had complete data for an average of 10.46 out of 12 time points ($SD = 2.62$), and 81.04% ($n = 808$) had complete data for at least 10 out of 12 time points. The number of time points with missing data was significantly correlated with baseline cannabis use ($r = .097$, $p < .005$), but not with baseline alcohol consumption ($p = .06$) or alcohol consequences ($p = .16$).

We first specified a model with total alcohol consequences as the outcome, and then each alcohol consequence subscale was specified as the outcome in separate models. As each subscale represented the number of relevant consequences endorsed in the past month, these outcomes were specified as count variables using a negative binomial link function to accommodate over-dispersion in the variables. All models used the robust maximum likelihood estimator.

In each model, level 1 (within-person) predictors included frequency of cannabis use and typical drinks per week at each time point in order to examine the independent contribution of changes in cannabis use to alcohol consequences while controlling for concurrent changes in alcohol consumption. If a participant reported no alcohol use in the past month at a given time point, the YAACQ was not administered and they received a score of zero for alcohol consequences at that time point. Including non-drinking time points in the analysis allowed us to examine the unique association between changes in cannabis use and the full range of alcohol consequences observed, including the absence of consequences due to past-month abstinence. Both cannabis use and alcohol use variables were person-mean centered at level 1, so that each observation represented within-person deviations from each participant's mean levels of use.

At level 1 of each model, we also included three dummy coded variables to control for month of assessment (with September as the reference category) and a linear trend for year (with year 1 coded as zero) to control for changes over the three years of the study. Level 2 (between-person) predictors in each model included person-level means representing each individual's average cannabis use frequency and average alcohol consumption aggregated across all time points. Level 2 covariates also included participants' sex and whether they screened positive for PTSD symptomatology during recruitment (no=0, yes=1). All level 2 covariates were grand-mean centered in analyses.

In all models, covariances between alcohol use and cannabis use were freely estimated at both level 1 and level 2. Random intercepts were estimated, and random slopes for the within-person associations of cannabis use and alcohol use with the alcohol consequence outcomes were also included in each model. We also tested whether freely estimating the covariances among random intercept and random slope factors improved model fit based on sample size adjusted Bayesian Information Criterion (aBIC).

Further, given that sex differences in the prospective associations between alcohol consequence domains and drinking outcomes have been previously reported (Read et al., 2013a), we also explored the moderating role of sex in the within-person associations between cannabis use and alcohol consequences. To do so, the random slope for the within-person association between cannabis use and the alcohol consequence outcome was regressed on sex in each model. A significant association between sex and variance in the random slope suggest that sex moderates the within-person association (i.e., cross-level interaction).

Results

Descriptive Statistics

Table 1 presents descriptive statistics for relevant study variables at each of the 12 time points included in the current study. At baseline, 19% of the sample endorsed past month cannabis use (n = 189). Of those who reported using cannabis at time 1, 33.3% reported using "*about once a month*" (n = 63), 33.9% *"2–3 times in the past month*" (n = 64), 14.8% "*once or twice a week*" (n = 28), 5.8% "*three to four times a week*" (n = 11), 6.8% "*nearly every day"* (n = 13), and 5.3% "*everyday*" (n = 10). At baseline, 63.99% (n=638) of the sample reported past month alcohol use, and the average number of drinks consumed in a typical week was 10.47 (SD=10.54) among the alcohol users. Average cannabis use frequency in the entire sample increased slightly over the course of the study (see Table 1), while typical drinks per week appeared to remain relatively stable on average, with peaks in alcohol consumption in September of each year (Table 1). Total alcohol consequences followed a similar pattern, but also showed a slight decline over the three years.

Multilevel Models

For the model predicting total alcohol consequences, allowing the random intercept and random slope factors to freely covary improved model fit based on the aBIC values (ΔaBIC = 9.616). Thus, the final model included these covariance parameters. However, freely estimating the covariances among the random intercept and random slopes factors did not improve model fit for any of the alcohol consequences subscales (all aBICs increased with these parameters included) and so they were omitted from the final models.[2]

Table 2 shows the results of each model. In the model with total alcohol consequences as the outcome, within-person changes in cannabis use frequency was not significantly associated with corresponding changes in alcohol consequences after accounting for changes in alcohol use. Further, between-person differences in average frequency of cannabis use did not uniquely predict total alcohol consequences after accounting for between-person differences in alcohol consumption (see Table 2).

However, when examining the associations separately for each subscale (Table 2), results showed that within-person changes in cannabis use frequency were uniquely associated with changes in the risky behaviors, dependence, and self-care domains of the YAACQ (controlling for changes in alcohol use). Within-person changes in cannabis use were not uniquely associated with changes in the other alcohol consequence types.

Further, at the between-person level, individuals who reported more frequent cannabis use overall (averaged across all time points) had greater average endorsement of risky behaviors and blackout consequence domains after controlling for between-person differences in alcohol consumption (see Table 1). There were no significant between-person associations between cannabis use and any of the other alcohol consequences subscales.

[2]Estimation problems were initially encountered when estimating the model predicting impaired control consequences. The problem was resolved by fixing the variance to zero for the random slope of the within-person association between cannabis use and impaired control consequences. Thus, the final did not include a random slope for this association.

Finally, to examine the moderating role of sex, each model was rerun with sex specified as a predictor of the random slope for the association between cannabis use and the alcohol consequence variable (with the exception of impaired control consequences as the random slope variance was fixed to zero in this model). Sex was not a significant predictor of the random slope variance in any model (all $p > .20$), suggesting that there were no sex differences in the within-person associations between changes in cannabis use and alcohol consequences.

Discussion

A sizable proportion of young adult drinkers also use cannabis (Midanik et al., 2007, Subbaraman and Kerr, 2015), and the prevalence of cannabis and alcohol co-use among young adults has generally risen in the last few decades (Terry-McElrath and Patrick, 2018). Given ongoing changes to cannabis regulations in the U.S. and around the world, it is important to understand the role of cannabis use in alcohol-related outcomes among young adults, as this may have implications for policies and interventions. Although several cross-sectional studies have established an association between cannabis use and greater alcohol-related harms (e.g., Egan et al., 2019, Jackson et al., 2020; Linden-Carmichael et al., 2019, Midanik et al., 2007, Shillington and Clapp, 2001, Subbaraman and Kerr, 2015), there have been few longitudinal studies of within-person associations between cannabis use and alcohol-related consequences, and most of these are of brief duration, focusing on daily-level associations (e.g., Linden-Carmichael et al., 2020, Lipperman-Kreda et al., 2017, Mallett et al., 2019). We sought to address this gap in the literature with a multi-year analysis of the link between within-person changes in cannabis use frequency and corresponding changes in alcohol consequences among young adults. Importantly, this study represents a significant extension of prior multi-year longitudinal research (e.g., Gunn et al., 2018) by examining the links between changes in cannabis use and specific domains of negative alcohol-related consequences.

We found that within-person changes in past 30 day cannabis use frequency (assessed 4 times per year over 3 years) were not associated with corresponding changes in total past 30 day alcohol consequences, after controlling for concurrent changes in past 30 day alcohol consumption. This finding is generally consistent with several short-term daily diary and EMA studies that have found little evidence that using cannabis on drinking days is independently associated with greater acute negative alcohol consequences after accounting for differences in level of alcohol consumption (Lipperman-Kreda et al., 2017, Mallett et al., 2019, Merrill et al., 2019). However, these findings are inconsistent with at least one short-term daily diary study (Linden-Carmichael et al., 2020), as well as the longer-term (2 year) study by Gunn et al. (2018) that did find a significant within-person association between changes in cannabis use and changes in alcohol consequences while controlling for changes in alcohol use. Given that associations between cannabis use and alcohol consequences observed in the present study varied across different domains of alcohol consequences, it is perhaps not surprising that we observed a null association when summing across all alcohol consequences domains; accordingly, the lack of convergence between our findings and those of Gunn et al. could be due to differences in the items comprising the measure of total negative alcohol consequences used in each of these studies.

Although cross-sectional studies have reported differential associations of cannabis-alcohol co-use with specific types of alcohol consequences (e.g., Jackson et al., 2020), previous longitudinal studies have tended to aggregate across a range of different negative alcohol consequences, which may obscure unique associations between cannabis use and specific alcohol consequence domains. Thus, a major objective of our study was to examine longitudinal associations between cannabis use and distinct alcohol consequence types ranging from lower to higher severity. An important finding that emerged from this examination is that within-person changes in cannabis use among young adults was uniquely associated with changes in some types of negative alcohol consequences but not others, a finding that may be helpful in providing some insight into the mixed findings in this literature to date.

Specifically, as cannabis and alcohol may have acute or chronic additive effects on cognitive and behavioural impairment (Yurasek et al., 2017), we hypothesized that increased cannabis use during a given time period would be uniquely associated during the same time period with increases in more severe alcohol consequence types, which may be more likely to emerge at greater levels of impairment. For example, consequences such as dependence symptoms and academic problems are not common among young adult drinkers (Read et al., 2006), and thus the additive impairment associated with co-use of cannabis and alcohol may make these consequences more likely to emerge in this population. Conversely, social consequences (e.g., saying embarrassing things while drinking) are much more common among young adults (Read et al., 2006) and are more likely to occur even at lower levels of alcohol impairment, perhaps making the additive impact of cannabis use less important after accounting for levels of drinking. We observed some support for this hypothesis in our analyses; within-person changes in cannabis use were uniquely associated with changes in only some of the less common (and more severe) consequence types, such as alcohol dependence symptoms, risky behaviors, and poor self-care. Yet, not all of the less common consequences (e.g., academic/occupational consequences) were predicted by within-person changes in cannabis use. Thus, further research elucidating mechanisms of these associations is required in order to help clarify the importance of the relative severity of alcohol consequences.

Interestingly, we also observed a significant between-person association between average cannabis use frequency and both greater blackout/hangover consequences and increased risky behaviours aggregated across time. In contrast, between-person differences in cannabis frequency were not uniquely associated with individual differences in the other alcohol consequence domains when controlling for between-person differences in alcohol use. One possible interpretation of this findings is that there may be some stable individual difference factors (e.g., impulsivity) not captured here that contribute to the association between cannabis use and certain types of consequences (e.g., those involving risky outcomes) relative to other types of consequences. Examination of the specific mechanisms that may account for these differential between-person relationships will be an interesting direction for future work.

Finally, we did not find evidence that sex moderated the within-person association between cannabis use and alcohol consequences. Thus, the strength of the longitudinal relationship

between changes in cannabis use frequency and changes in alcohol consequences was similar for young men and young women in this sample. Future research that incorporates a more comprehensive set of sex- and gender-based factors (e.g., gender identity, peer influences) is needed to clarify the role of sex in the link between cannabis use and alcohol consequences.

Some limitations should be considered when interpreting the results of this study. First, as past 30-day cannabis use and alcohol use were assessed at each time point, we are not able to determine whether participants who reported using both substances at the same time point used both substances on the same or separate occasions (i.e., simultaneous vs. concurrent use). Although previous research shows that the majority of young adults who co-use cannabis and alcohol report simultaneous use (Subbaraman and Kerr, 2020), in the current study it is not clear whether the associations we observed are due to the effects of simultaneous use or simply due to the concurrent use of cannabis during the same time period. Moreover, this assessment time frame precludes any inferences regarding the direction of the association between cannabis use and alcohol consequences.

Further, we used the relative levels of endorsement of each alcohol consequence domain as an index of the relative severity of the consequences. While this follows the logic underlying previous work on the severity of the individual YAACQ items (Kahler et al., 2005), no prior work has statistically examined the continuum of severity reflected in the YAACQ subscales. Thus, future research that statistically verifies the relative severity of consequences at the subscale level will be informative. Also, while the YAACQ assesses consequences that are explicitly attributed to alcohol use, it is possible that the observed relationship between increased cannabis use and increases in certain types of alcohol consequences may be driven to some extent by individuals misattributing cannabis consequences to their alcohol use. Indeed, a recent cross-sectional study found that college students who were simulatneous users of cannabis and alcohol tended to attribute their negative consequences to alcohol rather than to the combined use of alcohol and cannabis (Jackson et al., 2020). Thus, future longitudinal studies that assess the attribution of negative consequences to specific substances will be informative.

An additional limitation is that data were collected before the recent wave of recreational cannabis legalization that has occurred across the U.S. It is possible that more recent changes in cannabis prevalence, norms, and perceptions of risk could impact relationships between cannabis use and alcohol outcomes, and so the results should be replicated with future cohorts. Also, only frequency of cannabis use was assessed in this study. Although it is common for studies to focus only on cannabis frequency due to challenges in reliably assessing quantity (see Prince et al., 2018), future studies should incorporate recently validated measures (e.g., Cuttler and Spradlin, 2017) that assess cannabis quantity, cannabis type (e.g., dried cannabis flower, concentrates, edibles), and routes of administration (e.g., smoked, eaten, vaporized).

Finally, additional research is needed to elucidate the mechanisms of the within-person associations between cannabis use and alcohol consequences observed here. For example, the young adult years are marked by ongoing brain development (Casey et al., 2005),

changes in personality traits (Robins et al., 2001), and several life transitions (Arnett, 2005), all of which may be important for understanding longitudinal associations between cannabis use and alcohol consequences over time. Moreover, additional dynamic factors (e.g., life stressors, comorbid symptomatology) could act as third variables that account for the longitudinal associations between cannabis use and alcohol consequences. Future prospective studies are needed that control for additional relevant covariates and incorporate important mechanistic constructs that are relevant for understanding co-use in this developmental context (e.g., co-use motives and subjective effects of co-use; Lee et al. 2017, Patrick et al., 2018).

In summary, this study extends previous research on the unique contribution of cannabis use to alcohol-related consequences among young adults by examining longitudinal within-person associations between changes in cannabis use and changes in negative alcohol consequences over a period of several years. Our study underscores the importance of considering the longer-term impacts that within-person changes in cannabis use may have on alcohol outcomes. As changes in cannabis use appear to be related to changes in more severe alcohol consequences, the findings suggest that there may be utility in incorporating content on the link between cannabis and alcohol consequences into harm reduction interventions for young adult drinkers. Future research should examine whether interventions that target co-use of cannabis and alcohol or provide feedback on the specific types of alcohol consequences that are linked with cannabis use may help to improve intervention outcomes among young adult drinkers.

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Table 1.

Descriptive data for cannabis use, alcohol use and alcohol consequences at each time point

	Year 1			
	Sep	**Dec**	**Feb**	**Apr**
n complete	934	879	846	855
n co-users	173(18.5%)	108(12.3%)	121(14.3%)	115(13.5%)
Cannabis use[a]	0.45(1.11)	0.39(1.09)	0.42(1.13)	0.41(1.15)
Alcohol use[b]	6.42(9.70)	5.13(8.70)	6.02(9.80)	5.72(9.39)
YAACQ				
TOT	5.34(7.41)	3.24(6.20)	4.03(7.35)	3.73(6.77)
SOC	1.01(1.44)	0.61(1.24)	0.70(1.30)	0.67(1.29)
CONT	0.83(1.30)	0.52(1.11)	0.65(1.31)	0.60(1.2)
SELF-P	0.44(0.97)	0.26(0.76)	0.32(0.89)	0.29(0.79)
SELF-C	0.72(1.38)	0.48(1.27)	0.57(1.43)	0.51(1.26)
RISK	0.63(1.19)	0.31(0.87)	0.42(1.07)	0.39(1.05)
ACOC	0.26(0.74)	0.18(0.68)	0.28(0.88)	0.24(0.76)
DEP	0.21(0.54)	0.17(0.48)	0.19(0.54)	0.20(0.55)
BLK	1.24(1.81)	0.71(1.45)	0.88(1.62)	0.83(1.57)
	Year 2			
	Sep	**Dec**	**Feb**	**Apr**
n complete	889	867	857	843
n co-users	140(15.7%)	122(14.1%)	120(14.0%)	123(14.6%)
Cannabis use[a]	0.48(1.27)	0.49(1.32)	0.51(1.34)	0.53(1.40)
Alcohol use[b]	6.74(10.19)	5.38(8.35)	5.44(8.43)	5.24(8.35)
YAACQ				
TOT	4.14(7.12)	3.41(6.73)	3.42(6.69)	3.23(6.31)
SOC	0.78(1.35)	0.63(1.24)	0.60(1.24)	0.58(1.19)
CONT	0.66(1.25)	0.57(1.20)	0.55(1.13)	0.51(1.08)
SELF-P	0.32(0.85)	0.24(0.75)	0.26(0.76)	0.24(0.75)
SELF-C	0.57(1.33)	0.46(1.23)	0.44(1.19)	0.45(1.20)
RISK	0.48(1.14)	0.38(1.01)	0.39(1.04)	0.36(0.99)
ACOC	0.16(0.63)	0.22(0.78)	0.20(0.72)	0.20(0.70)
DEP	0.20(0.56)	0.16(0.49)	0.16(0.50)	0.14(0.44)
BLK	0.98(1.70)	0.75(1.50)	0.82(1.64)	0.75(1.46)
	Year 3			
	Sep	**Dec**	**Feb**	**Apr**
n complete	897	856	853	855
n co-users	149(16.6%)	122(14.3%)	124(14.5%)	118(13.8%)
Cannabis use[a]	0.57(1.42)	0.50(1.35)	0.52(1.33)	0.56(1.43)
Alcohol use[b]	6.22(9.17)	5.60(9.37)	5.95(8.91)	6.24(8.91)

YAACQ				
TOT	3.62(6.25)	3.16(5.88)	3.20(5.92)	3.55(6.14)
SOC	0.68(1.25)	0.60(1.17)	0.55(1.12)	0.63(1.17)
CONT	0.59(1.11)	0.49(1.01)	0.53(1.08)	0.62(1.16)
SELF-P	0.23(0.67)	0.20(0.70)	0.21(0.69)	0.26(0.78)
SELF-C	0.52(1.30)	0.46(1.23)	0.45(1.21)	0.51(1.25)
RISK	0.46(1.12)	0.33(0.93)	0.32(0.89)	0.36(0.93)
ACOC	0.14(0.54)	0.16(0.63)	0.13(0.53)	0.20(0.68)
DEP	0.15(0.43)	0.15(0.46)	0.18(0.49)	0.16(0.47)
BLK	0.85(1.51)	0.77(1.44)	0.83(1.53)	0.81(1.46)

Notes. Means shown with standard deviations in parentheses.

[a]Cannabis use frequency (past 30 days) coded 0=*Never in the past month*, 1=*About once in the past month*, 2=2–3 *times in the past month*, 3=*Once or twice a week*, 4=*Three to four times a week*, 5=*Nearly every day*, 7=*Every day*.

[b]Typical drinks per week in the past month from the Daily Drinking Questionnaire.

YAACQ=Young Adult Alcohol Consequences Questionnaire; TOT=total consequences; SOC=social/interpersonal consequences; CONT=impaired control consequences; SELF-P=self-perception consequences; SELF-C=self-care consequences; RISK=risk behaviors; ACOC=academic/occupational consequences; DEP=dependence consequences; BLK=blackout consequences.

Table 2.

Unstandardized parameter estimates (standard errors in parentheses) for the multilevel models predicting total alcohol consequences and each of the alcohol consequence subscales.

	Alcohol Consequence Outcomes								
	TOT	**BLK**	**SOC**	**CONT**	**RISK**	**ACOC**	**SELF-P**	**SELF-C**	**DEP**
Within-Person[a]									
Random slopes:[b]									
Can Use→Alc Cons:									
Mean	0.04(0.04)	0.02(0.03)	0.01(0.02)	0.02(0.02)	0.08(0.02)**	0.05(0.03)	−0.06(0.04)	0.06(0.02)**	0.07(0.03)*
Variance	<0.01(<0.01)	<0.01(<0.01)	0.01(0.01)	0[c]	<0.01(<0.01)	<0.01(<0.01)**	<0.01(<0.01)**	<0.01(<0.01)	0.02(0.03)
Alc Use→Alc Cons:									
Mean	2.25(0.31)**	1.08(0.08)**	0.88(0.08)**	0.99(0.07)**	0.87(0.07)**	0.95(0.09)**	0.94(0.09)**	0.98(0.07)**	0.77(0.09)**
Variance	2.69(0.77)**	0.54(0.11)**	0.47(0.12)**	0.48(0.08)**	0.37(0.08)**	0.33(0.09)**	0.46(0.13)**	0.47(0.10)**	0.21(0.06)**
Covariance:									
Can Use – Alc Use	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**	0.04(0.01)**
Dispersion	0.73(0.05)**	0.24(0.04)**	0.07(0.04)	0.01(0.03)	0.36(0.07)**	0.75(0.15)**	1.09(0.15)**	0.32(0.06)**	<0.01(0.37)
Between-Person									
Slopes:									
Average Can Use	0.07(0.04)	0.12(0.03)**	0.02(0.04)	0.05(0.04)	0.14(0.04)**	0.09(0.06)	−0.09(0.05)	0.05(0.06)	>−0.01(0.05)
Average Alc Use	1.17(0.40)**	1.30(0.10)**	1.19(0.10)**	1.20(0.10)**	1.28(0.12)**	1.35(0.13)**	0.88(0.10)**	1.38(0.12)**	1.22(0.11)**
Male sex	−0.61(0.09)**	−0.61(0.08)**	−0.58(0.09)**	−0.59(0.10)**	−0.44(0.12)**	−0.45(0.15)**	−0.41(0.14)**	−0.46(0.13)**	−0.40(0.12)**
Positive PTSD screen	0.39(0.09)**	0.17(0.08)*	0.29(0.09)**	0.40(0.09)**	0.49(0.11)**	0.50(0.14)**	0.48(0.13)**	0.61(0.12)**	0.57(0.12)**
Covariance:									
Can Use – Alc Use	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**	0.37(0.05)**

Notes.

[a]Fixed effects for assessment month (December vs. September, February vs. September, April vs. September) and Year (0=year 1, 1=year 2, 2=year 3) were included at level 1 of the multilevel model, but parameter estimates for these covariates are not shown to help simplify the table.

[b]The random slope is for the within-person associations of cannabis frequency and alcohol consumption with alcohol consequences. Because the values of the slopes vary across participants, the random slopes are estimated as a between-person latent variable with the mean representing the average within-person association and the variance representing the amount of variability in the slope across participants.

[c]The random slope variance was fixed to zero to facilitate estimation.

Can=Cannabis; Alc=Alcohol; Cons=consequences; PTSD=posttraumatic stress disorder; TOT=total consequences; BLK=blackout consequences; SOC=social/interpersonal consequences; CONT=impaired control consequences; RISK=risk behaviors; ACOC=academic/occupational consequences; SELF-P=self-perception consequences; SELF-C=self-care consequences; DEP=dependence consequences;

*p<.05;

**p<.01