

# UCSF

## UC San Francisco Previously Published Works

### Title

Perceived reward from using cigarettes with alcohol or cannabis and concurrent use: A smartphone-based daily diary study

### Permalink

<https://escholarship.org/uc/item/96r4d335>

### Authors

Thrul, Johannes

Gubner, Noah R

Nguyen, Nhung

et al.

### Publication Date

2021-03-01

### DOI

10.1016/j.addbeh.2020.106747

### Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed



Published in final edited form as:

*Addict Behav.* 2021 March ; 114: 106747. doi:10.1016/j.addbeh.2020.106747.

## Perceived reward from using cigarettes with alcohol or cannabis and concurrent use: A smartphone-based daily diary study

Johannes Thrul, PhD<sup>1,2,3</sup>, Noah R. Gubner, PhD<sup>4</sup>, Nhung Nguyen, PhD<sup>5</sup>, Charlie Nguyen<sup>1</sup>, Erin Anderson Goodell, PhD ScM<sup>1</sup>, Louisa M. Holmes, PhD<sup>6</sup>, Ryan G. Vandrey, PhD<sup>7</sup>, Pamela M. Ling, MD MPH<sup>5</sup>

<sup>1</sup>Department of Mental Health, Johns Hopkins Bloomberg School of Public Health

<sup>2</sup>Sidney Kimmel Comprehensive Cancer Center at Johns Hopkins

<sup>3</sup>Centre for Alcohol Policy Research, La Trobe University

<sup>4</sup>Department of Psychiatry and Weill Institute for Neurosciences, University of California, San Francisco

<sup>5</sup>Center for Tobacco Control Research and Education, University of California, San Francisco

<sup>6</sup>Department of Geography, Penn State University

<sup>7</sup>Department of Psychiatry and Behavioral Sciences, Johns Hopkins School of Medicine

### Abstract

**Introduction:** Smoking cigarettes under the influence of alcohol or cannabis is associated with perceived pleasure. However, it is unclear whether these changes in perceived reward impact the extent of cigarette concurrent use with alcohol or cannabis. The current study investigated if self-reported changes in perceived reward from concurrent use of cigarettes with alcohol or cannabis are related to the extent of concurrent use in real-world contexts using a smartphone-based Ecological Momentary Assessment (EMA) study.

**Methods:** The sample included 126 diverse young adult smokers in the San Francisco Bay area who also reported current alcohol or cannabis use at baseline (M=22.8 years, 50.8% male, 40.5% sexual minority, 39.7% Non-Hispanic White). Participants completed an online baseline survey and 30 days of smartphone-based daily EMA surveys of cigarette, alcohol, and cannabis use. The baseline assessed self-reported changes in perceived pleasure of smoking cigarettes while using

---

**Corresponding author:** Johannes Thrul, Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, 624 N Broadway, Room 887, Baltimore, MD 21205, Tel +1-410-502-0925, jthrul@jhu.edu.

Contributors

**JT:** Conceptualization, Methodology, Data analysis, Writing - original draft, Writing - review & editing. **NRG:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **NN:** Writing - review & editing. **CN:** Writing - original draft, Writing - review & editing. **EAG:** Writing - review & editing. **LMH:** Writing - review & editing. **RGV:** Writing - review & editing. **PML:** Conceptualization, Writing - review & editing, Supervision.

**Publisher's Disclaimer:** This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Author disclosures

No conflicts of interest reported.

alcohol or cannabis separately. EMA surveys included detailed questions about concurrent use (i.e., the extent of smoking while using another substance) covering the previous day. A total of 2,600 daily assessments were analyzed using mixed models.

**Results:** Higher perceived pleasure from smoking cigarettes while drinking alcohol or using cannabis at baseline were both associated with a greater extent of concurrent use of cigarettes with alcohol ( $b=0.140$ ;  $SE=0.066$ ;  $t=2.1$ ;  $p=.035$ ) and cannabis ( $b=0.136$ ;  $SE=0.058$ ;  $t=2.4$ ;  $p=.019$ ) on a given day.

**Conclusions:** Results suggest that perceived reward from concurrently using cigarettes with alcohol or cannabis is associated with the extent of concurrent use. Findings can inform tailored smoking cessation interventions.

## Keywords

tobacco; alcohol; cannabis; young adults; Ecological Momentary Assessment; daily diaries; smartphones

---

## 1. Introduction

Tobacco use is the greatest lifestyle contributor to morbidity and premature mortality in the US (U.S. Department of Health and Human Services, 2014) and young adults have a high prevalence of smoking (Kasza et al., 2017). Cigarette smoking has been found to be associated with both alcohol (Falk et al., 2006; McKee et al., 2007) and cannabis use (Agrawal et al., 2012; Goodwin et al., 2018; Lemyre et al., 2019; Ramo et al., 2012). Given the importance of concurrent use of tobacco with alcohol or cannabis in maintaining nicotine dependence and hindering smoking cessation, studies are needed to better characterize patterns of concurrent use in real-world contexts and understand reasons for this association.

The association between tobacco and alcohol use has been frequently documented in the existing literature. Tobacco use is high among heavy drinkers and binge drinkers (Falk et al., 2006; Gubner et al., 2016; Harrison and McKee, 2011). Cigarettes and alcohol have greater rewarding effects when used together (McKee et al., 2004; Nichter et al., 2006; Stromberg et al., 2007; Thrul et al., 2019), and combined pharmacological effects may contribute to their high rate of concurrent use.

Similarly to documented associations between tobacco and alcohol, cannabis use and cannabis use disorders are more common among cigarette smokers compared to non-smokers (Cohn et al., 2019; Conway et al., 2017; Holmes et al., 2016; Nguyen et al., 2019), and young adults who use cannabis are heavier smokers and report greater nicotine dependence (Agrawal and Lynskey, 2009; Patton et al., 2006). Research indicates that cannabinoid receptors may be involved in the rewarding effects of nicotine. Nicotine and tetrahydrocannabinol (THC) activate shared neurobiological pathways, which may explain some overlap in the co-use of cannabis and tobacco and shared genetic risk for these two substances (Agrawal et al., 2010; Oleson and Cheer, 2012; Rabin and George, 2015). While some studies have found that cannabis use may increase the rewarding and reinforcing effects of nicotine (Gamaledin et al., 2012; Navarrete et al., 2013; Subramaniam et al., 2016), other studies have reported no difference in rewarding effects of smoking cigarettes

when under the influence of cannabis (Gubner et al., 2018). Reasons for concurrently using tobacco and cannabis include to enhance the high from cannabis or to counteract certain effects of cannabis (Antognoli et al., 2018; Berg et al., 2018; Schauer et al., 2016). However, existing studies have mostly relied on retrospective recall of substance use and co-use, and there is a lack of studies investigating concurrent use of cigarettes, cannabis, and alcohol use in real-world contexts.

In a previous study we showed that young adult smokers who also used alcohol and cannabis reported an increase in perceived pleasure from smoking cigarettes when drinking alcohol, while there was no change in perceived pleasure from smoking cigarettes when using cannabis (Gubner et al., 2018). However, our previous work relied on retrospective self-reports. Fine grained data on concurrent use, including those collected by Ecological Momentary Assessment (EMA) and daily diaries, are important to ameliorate retrospective recall bias, which is a limitation of survey research (Shiffman, 2009). Repeated assessments in temporal proximity to substance use events in EMA designs improve the reliability of collected data and EMA studies to investigate the concurrent use of tobacco and cannabis have been recommended in the recent literature (Nguyen et al., 2020b; Schlienz and Lee, 2018). To the best of our knowledge there is only one published study in this area, which collected 1 week of EMA data in a sample of young adults and found that working memory was impacted by acute effects of tobacco, cannabis, and alcohol use in the natural environment (Schuster et al., 2016). However, this study did not investigate subjectively reported rewards from concurrent use or extent of concurrent use, which is the focus of the current investigation.

To expand the existing literature, the current study investigated how self-reported changes in perceived pleasure from concurrently using cigarettes with alcohol or cannabis is associated with the extent of cigarette and alcohol and cigarette and cannabis concurrent use collected by daily diary in real-world contexts. Resulting findings can make an important contribution to developing public health approaches to curb concurrent use of cigarettes with other substances and inform tailored smoking cessation interventions.

## 2. Methods

### 2.1 Procedure

The study was conducted in the San Francisco Bay Area, California in 2016 and 2017. All study procedures were approved by the UCSF IRB. At baseline, participants completed an online survey via Qualtrics that assessed demographics, cigarette smoking history, alcohol, and cannabis use. An EMA training was conducted remotely on the phone, participants received a link to a training video, and a list of FAQs was available throughout the study on the EMA app. The training stressed the importance of high compliance for data quality and encouraged participants to reach out to the study team with any questions or problems. During each day of the 30-day study period, participants completed up to 7 EMA surveys on their own smartphone using the study app ([www.pilrhealth.com](http://www.pilrhealth.com)) (Nguyen et al., 2018). Of these surveys, 6 assessed the momentary context in real time throughout the day and one was a daily diary assessing substance use during the entire previous day. The daily diary was prompted between 10–11 AM and was available for completion for 12 hours. We selected

the morning of the next day instead of the evening of the same day in order to not miss substance use occasions that may occur late in the evening or at night. Incentives for completing EMA surveys were tied to participant compliance and final incentive amounts ranged from \$0 to \$120, distributed via online gift cards. Since momentary EMA surveys did not include detailed questions on cigarette concurrent use with alcohol or cannabis, analyses for the current manuscript are solely based on the daily diary assessments.

## 2.2 Participants

Participants were recruited through advertisements on Facebook and Instagram targeted at the general population of young adult smokers. To conduct a nested qualitative sub-study investigating tobacco use among sexual minority young adults (McQuoid et al., 2019, 2018), additional recruitment efforts used websites of sexual minority youth organizations and the study oversampled women identifying as sexual minority. Sexual minority young adults are important to include in a study on concurrent substance use, since the existing literature has demonstrated high rates of tobacco, alcohol, and cannabis use and concurrent use in this vulnerable group of young people (Dermody, 2018; Nguyen et al., 2020a). Eligible participants were 18–26 years of age, had smoked at least 100 cigarettes in their lifetime, currently smoked at least one cigarette per day at least three days per week, and made daily use of a smartphone. Eligible participants were required to send a picture of their ID to verify their identity.

Overall, 230 smokers were screened successfully, 184 completed the baseline assessment, and 147 responded to at least one daily diary survey. For the current study, we retained participants who reported any concurrent use of cigarettes and alcohol or cigarettes and cannabis in daily diaries over the 30-day data collection period. This excluded 21 participants for an analytic sample of 126 participants. Included and excluded participants did not significantly differ on any baseline variables with the exception of past month number of days of cannabis use (included:  $M=12.4$ ,  $SD=12.1$ ; excluded:  $M=5.9$ ,  $SD=11.9$ ).

## 2.3 Measures

**2.3.1 Baseline demographics**—Data on demographics (e.g., age, gender and sexual identity, race/ethnicity, educational attainment), and frequency of cigarette, alcohol, and cannabis use in the last 30 days were collected.

**2.3.2 Baseline changes in perceived pleasure from concurrent use**—Changes in perceived pleasure from concurrently using cigarettes with alcohol or cannabis were assessed at baseline with 2 questions (“How does your pleasure from smoking cigarettes change when you are drinking ALCOHOL?”; “How does your pleasure from smoking cigarettes change when you are using MARIJUANA?”). Responses were recorded on a 5-point Likert scale (1 – strongly decrease to 5 – strongly increase; with midpoint 3 – no change). These questions were based on our previously conducted studies (Gubner et al., 2018; Thrul et al., 2019) and only asked of participants who reported cigarette and alcohol/cannabis use in the past 30 days.

**2.3.3 Daily diary covariates**—Every day for 30 days, participants completed a daily diary reporting their substance use on the entire previous day. Participants were asked if they had smoked on the previous day (yes/no) and number of cigarettes was assessed on a 7-point scale (1 to 31+). To approximate a continuous scale for analysis, we used midpoints of categories and 33.75 for the highest category (Thrul and Kuntsche, 2015). Participants were asked if they consumed any alcohol on the previous day (yes/no) and number of drinks was assessed on a 7-point scale (1 to 7+). Any cannabis use on the previous day and number of times of cannabis use was assessed in the same way as alcohol use.

**2.3.4 Concurrent use outcome variables collected by daily diary**—On days when participants reported using both cigarettes and alcohol or cigarettes and cannabis, additional questions assessed concurrent use. The first set of questions assessed any concurrent use of cigarettes and alcohol or cigarettes and cannabis separately and responses were coded dichotomously (yes/no). If any concurrent use of cigarettes and alcohol or cigarettes and cannabis was reported, a second set of questions assessed the extent of concurrent use for the substances in question (“YESTERDAY: How many of your cigarettes did you smoke while drinking alcohol?/while using marijuana?”) and responses were recorded on a 4-point Likert scale (1–None of them to 4–All of them). For analyses, a “no” on the first set of questions assessing any concurrent use was counted towards the category “1-None of them”, since it indicated that the participant had used both substances on the previous day (concurrent use questions were only displayed when any use was reported), but not concurrently in the same occasion.

## 2.4 Statistical analyses

Multilevel mixed-effects models were estimated to investigate how changes in perceived pleasure from concurrently using cigarettes with alcohol or cannabis were associated with day-to-day cigarette and alcohol or cigarette and cannabis concurrent use, accounting for assessment days clustered within participants. Linear models examined factors associated with the extent of concurrent use of cigarettes and alcohol and cigarettes and cannabis on a given day. The main predictors of interest were changes in perceived pleasure from smoking when drinking alcohol and when using cannabis, as reported at baseline. Analyses were adjusted for daily diary variables, such as number of cigarettes, standard drinks (for alcohol models), number of times used cannabis (for cannabis models), and baseline variables (i.e., age, gender identity, sexual identity, race/ethnicity, and education). We used the `-margins-` command in Stata 16 to derive predicted scores of the outcome for different levels of the main predictor. Sensitivity analyses included additional covariates e-cigarette use (day), mental distress (baseline), and nicotine dependence (baseline) and are described in detail in the online supplement.

## 3. Results

### 3.1 Sample description – baseline characteristics

Participants were young adults (mean age 22.8), over half were male, and 40.5% self-identified as sexual minority (Table 1). The largest racial group was Non-Hispanic White (39.7%) and the majority of participants (77.8%) were either currently in or had graduated

college. At baseline, participants reported smoking cigarettes on an average of 25.3 days, using alcohol on 11.3 days, and using cannabis on 12.4 days (of the past 30 days). All 126 participants reported using alcohol in the past 30 days, while 90 participants reported cannabis use in the past 30 days. The question about changes in perceived pleasure from smoking cigarettes while using cannabis was only asked to these 90 participants.

At baseline, participants reported a mean of 4.3 (SD=0.8) for perceived pleasure when smoking cigarettes with alcohol (scale from 1 “strong decrease” to 5 “strong increase”), which was significantly different from 3 (“no change”;  $t(125)=17.7$ ;  $p<.001$ ). A total of 91.3% of participants reported that alcohol either strongly or moderately increased their perceived pleasure from smoking cigarettes. Participants also reported a mean perceived pleasure from smoking cigarettes with cannabis of 3.1 (SD=1.2), which was not significantly different from 3 (“no change”;  $t(89)=0.9$ ;  $p=.38$ ). Only 43.3% of participants reported that cannabis strongly or moderately increased their perceived pleasure from smoking cigarettes.

### 3.2 Daily diary data description

A total of 2,600 daily diaries were collected, amounting to an average of 20.6 days per participant or a 68.6% compliance rate over the 30-day data collection period. Both cigarette and alcohol use were reported on 34.5% of days and both cigarette and cannabis use on 34.6% of days (Table 2). Any cigarette and alcohol concurrent use was reported on 74.1% of cigarette-alcohol use days; and cigarette and cannabis concurrent use on 55.7% of cigarette-cannabis use days. Regarding the extent of cigarette and alcohol concurrent use, participants most frequently reported smoking some cigarettes with alcohol (39.3%), while for extent of cigarette and cannabis concurrent use, participants most frequently reported smoking none of their cigarettes with cannabis (43.3%).

### 3.3 Multilevel mixed-models

**3.3.1 Cigarettes and alcohol.**—Higher perceived pleasure from smoking cigarettes while drinking alcohol at baseline was associated with a greater extent of concurrent use of cigarettes with alcohol ( $b=0.140$ ;  $SE=0.066$ ;  $t=2.1$ ;  $p=.035$ ). On average, the predicted score of extent of concurrent use of cigarettes and alcohol was  $M=2.318$  among those who reported a “strong increase” in perceived reward at baseline as opposed to a score of  $M=2.039$  among those who reported “no change” and a score of  $M=1.760$  among those who reported a “strong decrease”.

**3.3.2 Cigarettes and cannabis.**—Higher perceived pleasure from smoking cigarettes while using cannabis at baseline was associated with a greater extent of concurrent use of cigarettes with cannabis ( $b=0.136$ ;  $SE=0.058$ ;  $t=2.4$ ;  $p=.019$ ). On average, the predicted score of extent of concurrent use of cigarettes and cannabis was  $M=2.221$  among those who reported a “strong increase” in perceived reward at baseline as opposed to a score of  $M=1.864$  among those who reported “no change” and a score of  $M=1.492$  among those who reported a “strong decrease”.

### 3.4 Sensitivity analyses

Sensitivity analyses including covariates e-cigarette use (day), mental distress (baseline), and nicotine dependence (baseline) were conducted and associations between self-reported change in perceived pleasure and extent of concurrent use remained consistent and significant for both alcohol and cannabis models. For details please refer to the online supplement.

## 4. Discussion

This study investigated how changes in perceived pleasure from concurrently using cigarettes with alcohol or cannabis were associated with concurrent use of cigarettes and alcohol or cigarettes and cannabis, collected by daily diaries. Greater perceived pleasure from concurrently using cigarettes with alcohol or cannabis was associated with a greater proportion of cigarettes smoked with alcohol or with cannabis on a given day, respectively.

This study demonstrates the utility of daily diaries to study cigarette concurrent use with alcohol and cannabis. By assessing day-to-day concurrent use with smartphone-based assessments, we expand on previous retrospective survey studies investigating concurrent use of tobacco and other substances (Gubner et al., 2018; McKee et al., 2007; Schauer et al., 2015; Thrul et al., 2019). Participants reported a substantial amount of concurrent use: Cigarette-alcohol concurrent use was reported on 25.4% of sampled days and cigarette-cannabis concurrent use was reported on 19.6% of sampled days. In contrast to a definition of co-use as any use of two substances in the past 30 days, as frequently used in retrospective surveys (Gubner et al., 2018; Schauer et al., 2015), fine grained data collected in the context of the present study provide more detailed information on concurrent use patterns by reducing recall bias and allow for novel analyses of potentially higher risk concurrent use behaviors.

Our findings on greater perceived pleasure from smoking cigarettes under the influence of alcohol are consistent with the existing literature (Gubner et al., 2018; McKee et al., 2004; Thrul et al., 2019). Both nicotine and alcohol can induce dopamine release in the nucleus accumbens, suggesting these drugs may share a common mechanism of action through activating the mesolimbic dopamine pathway (Verplaetse and McKee, 2017). However, our findings also extend the existing literature, since to the best of our knowledge our study is the first to report that changes in perceived pleasure were associated with concurrent use of cigarettes and alcohol in a daily diary design.

In a previous study we found that, on average, young adults did not report an increase in perceived pleasure from smoking cigarettes while using cannabis (Gubner et al., 2018), and these results are confirmed in the current study. However, the current study found that changes in perceived pleasure were associated with daily concurrent use of cigarettes with cannabis. On the one hand this means that, on average, rewarding effects from smoking cigarettes under the influence of alcohol are greater compared to rewarding effects of smoking cigarettes under the influence of cannabis. On the other hand, we observed that there is a range of participant experiences with regards to changes in perceived pleasure from smoking cigarettes under the influence of cannabis: While some participants perceived



smoking cigarettes under the influence of cannabis as more rewarding, others perceived them as less rewarding. More importantly, our findings suggest that those who perceive an increase in pleasure are more likely to concurrently use cigarettes and cannabis. Further work is needed to identify the behavioral and genetic factors that contribute to individual differences in the perceived pleasure of concurrent cigarette and cannabis use.

Implications of the current work include that findings may inform efforts to tailor and improve smoking cessation interventions for young adult smokers. These interventions need to address perceived pleasure, particularly among those who concurrently use cigarettes with alcohol or cannabis. While alcohol use as a risk factor for smoking relapse is recognized and included as part of standard smoking cessation interventions (Fiore et al., 2008), the concurrent use of cigarettes and cannabis is addressed less often (Becker et al., 2013). Future studies could investigate if changes in perceived pleasure from concurrent use puts individuals at increased risk for smoking relapse. Asking smokers who report concurrent use of cigarettes with alcohol or cannabis about changes in perceived pleasure may offer an opportunity to tailor smoking cessation interventions to address these specific risk factors.

The current study may also have important implications for public health. Tobacco companies have done extensive research on the concurrent use of cigarettes and alcohol and have utilized this knowledge to develop a number of targeted marketing strategies (Jiang and Ling, 2011). Pleasure has also been a longstanding theme promoting cigarette sales (Anderson, 2011). As our study also found a substantial amount of cigarette and cannabis concurrent use among young adults, the public health community will have to be mindful of potential targeted cross-product marketing approaches between tobacco and cannabis in the context of cannabis legalization in many US states.

#### 4.1 Limitations

The sample for the current study consisted of young adult smokers in the San Francisco Bay Area and may not be generalizable to other populations. The concurrent use measures used in daily EMA surveys of this study are not validated, and replication of these findings is needed. Moreover, it is unclear if changes in perceived rewards from concurrently using cigarettes with alcohol or cannabis are due to pharmacological interactions or characteristics of concurrent use situations. For example, concurrent use may be perceived as more rewarding because it happens in otherwise enjoyable situations (during a night out, with friends, etc.). Future studies controlling for situational characteristics are needed to disentangle these potential confounders. We did not assess the overlap between cigarettes smoked when both drinking alcohol and using cannabis or mode of cannabis use (e.g., smoked, vaporized, ingested). We also focused exclusively on the enhancement of perceived pleasure of smoking cigarettes by alcohol or cannabis rather than the ability of cigarettes to enhance the pleasurable effects of other substances. Previous work suggests the direction we assessed was likely to be more affected, with individuals deriving more pleasure from smoking cigarettes while drinking compared to pleasure from drinking alcohol when smoking cigarettes (McKee et al., 2004). Moreover, another study found that tobacco did not impact the rewarding effects of cannabis (Hindocha et al., 2017). In light of popularity of alternative tobacco products among young adults, especially e-cigarettes (Dai and Leventhal,

2019), more research on concurrent use of e-cigarettes and alcohol or cannabis is needed (Thrul et al., 2019). Lastly, we did not assess simultaneous use of tobacco and cannabis in blunts or spliffs.

However, this study also has important strengths. Notably, the study is one of the first to investigate cigarette concurrent use with alcohol and cannabis using EMA and smartphone-based daily assessments, highlighting the utility of EMA designs to investigate concurrent use of multiple substances (Nguyen et al., 2020b; Shiffman, 2009). Moreover, the design allowed us to analyze how changes in perceived pleasure from co-using predicted the extent of co-use, which advances previous cross-sectional studies (Gubner et al., 2018). Another advantage is the diverse sample of young adult smokers, both in terms of racial and ethnic diversity and sexual minority status.

## 4.2 Conclusions

Results suggest that perceived reward from concurrently using cigarettes with alcohol or cannabis is associated with the extent of concurrent use assessed by smartphone-based daily diaries. Individual differences in experiencing changes in pleasure from concurrent use could correspond with greater risk for developing problematic substance use or concurrent use patterns. As young adult social environments are rich with alcohol advertising and likely to have increased cannabis advertising with legalization of recreational use, messages reinforcing perceptions of pleasure may further encourage concurrent use of cigarettes, alcohol, and cannabis. Public health interventions addressing these concurrent use patterns and motivators are needed.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Role of funding source

This study was supported by the National Cancer Institute (T32 CA113710; U01 CA154240), the National Institute on Drug Abuse (T32 DA007292), and the California Tobacco-Related Disease Research Program (TRDRP 25FT-0009).

## References

- Agrawal A, Budney AJ, Lynskey MT, 2012 The co-occurring use and misuse of cannabis and tobacco: a review. *Addiction* 107, 1221–1233. 10.1111/j.1360-0443.2012.03837.x [PubMed: 22300456]
- Agrawal A, Lynskey MT, 2009 Tobacco and cannabis co-occurrence: does route of administration matter? *Drug Alcohol Depend.* 99, 240–247. 10.1016/j.drugalcdep.2008.08.007 [PubMed: 18926646]
- Agrawal A, Silberg JL, Lynskey MT, Maes HH, Eaves LJ, 2010 Mechanisms underlying the lifetime co-occurrence of tobacco and cannabis use in adolescent and young adult twins. *Drug Alcohol Depend.* 108, 49–55. 10.1016/j.drugalcdep.2009.11.016 [PubMed: 20047801]
- Anderson SJ, 2011 Marketing of menthol cigarettes and consumer perceptions: a review of tobacco industry documents. *Tob. Control* 20, ii20–ii28. 10.1136/tc.2010.041939 [PubMed: 21504928]
- Antognoli E, Koopman Gonzalez S, Trapl E, Cavallo D, Lim R, Lavanty B, Flocke S, 2018 The Social Context of Adolescent Co-Use of Cigarillos and Marijuana Blunts. *Subst. Use Misuse* 53, 654–661. 10.1080/10826084.2017.1355388

- Becker J, Hungerbuehler I, Berg O, Szamrovicz M, Haubensack A, Kormann A, Schaub MP, 2013 Development of an integrative cessation program for co-smokers of cigarettes and cannabis: demand analysis, program description, and acceptability. *Subst. Abuse Treat. Prev. Policy* 8, 33 10.1186/1747-597X-8-33 [PubMed: 24025478]
- Berg CJ, Payne J, Henriksen L, Cavazos-Rehg P, Getachew B, Schauer GL, Haardörfer R, 2018 Reasons for Marijuana and Tobacco Co-use Among Young Adults: A Mixed Methods Scale Development Study. *Subst. Use Misuse* 53, 357–369. 10.1080/10826084.2017.1327978 [PubMed: 28792283]
- Cohn AM, Abudayyeh H, Perreras L, Peters EN, 2019 Patterns and correlates of the co-use of marijuana with any tobacco and individual tobacco products in young adults from Wave 2 of the PATH Study. *Addict. Behav* 92, 122–127. 10.1016/j.addbeh.2018.12.025 [PubMed: 30623805]
- Conway KP, Green VR, Kasza KA, Silveira ML, Borek N, Kimmel HL, Sargent JD, Stanton C, Lambert E, Hilmi N, Reissig CJ, Jackson KJ, Tanski SE, Maklan D, Hyland AJ, Compton WM, 2017 Co-occurrence of tobacco product use, substance use, and mental health problems among adults: Findings from Wave 1 (2013–2014) of the Population Assessment of Tobacco and Health (PATH) Study. *Drug Alcohol Depend.* 177, 104–111. 10.1016/j.drugalcdep.2017.03.032 [PubMed: 28582698]
- Dai H, Leventhal AM, 2019 Prevalence of e-Cigarette Use Among Adults in the United States, 2014–2018. *JAMA.* 10.1001/jama.2019.15331
- Dermoddy SS, 2018 Risk of polysubstance use among sexual minority and heterosexual youth. *Drug Alcohol Depend.* 192, 38–44. 10.1016/j.drugalcdep.2018.07.030 [PubMed: 30205306]
- Falk DE, Yi H, Hiller-Sturmhöfel S, 2006 An epidemiologic analysis of co-occurring alcohol and tobacco use and disorders: findings from the National Epidemiologic Survey on Alcohol and Related Conditions. *Alcohol Res. Health* 29, 162–171. [PubMed: 17373404]
- Fiore MC, Jaén CR, Baker TB, Bailey WC, Benowitz NL, Curry SJ, Dorfman SF, Froelicher ES, Goldstein MG, Healton CG, Henderson PN, Heyman RB, 2008 Treating Tobacco Use and Dependence: 2008 Update: Clinical Practice Guideline. U.S. Department of Health and Human Services, Public Health Service, Rockville, MD.
- Gamaledin I, Wertheim C, Zhu AZX, Coen KM, Vemuri K, Makryannis A, Goldberg SR, Le Foll B, 2012 Cannabinoid receptor stimulation increases motivation for nicotine and nicotine seeking. *Addict. Biol* 17, 47–61. 10.1111/j.1369-1600.2011.00314.x [PubMed: 21521420]
- Goodwin RD, Pacek LR, Copeland J, Moeller SJ, Dierker L, Weinberger A, Gbedemah M, Zvolensky MJ, Wall MM, Hasin DS, 2018 Trends in Daily Cannabis Use Among Cigarette Smokers: United States, 2002–2014. *Am. J. Public Health* 108, 137–142. 10.2105/AJPH.2017.304050 [PubMed: 29161058]
- Gubner NR, Delucchi KL, Ramo DE, 2016 Associations between binge drinking frequency and tobacco use among young adults. *Addict. Behav* 60, 191–196. 10.1016/j.addbeh.2016.04.019 [PubMed: 27156220]
- Gubner NR, Thrul J, Kelly OA, Ramo DE, 2018 Young adults report increased pleasure from smoking cigarettes when drinking alcohol but not when using marijuana. *Addict. Res. Theory* 26, 71–76. 10.1080/16066359.2017.1311877 [PubMed: 29371859]
- Harrison ELR, McKee SA, 2011 Non-daily smoking predicts hazardous drinking and alcohol use disorders in young adults in a longitudinal U.S. sample. *Drug Alcohol Depend.* 118, 78–82. 10.1016/j.drugalcdep.2011.02.022 [PubMed: 21441000]
- Hindocha C, Lawn W, Freeman TP, Curran HV, 2017 Individual and combined effects of cannabis and tobacco on drug reward processing in non-dependent users. *Psychopharmacology (Berl.)* 234, 3153–3163. 10.1007/s00213-017-4698-2 [PubMed: 28733813]
- Holmes LM, Popova L, Ling PM, 2016 State of transition: Marijuana use among young adults in the San Francisco Bay Area. *Prev. Med* 90, 11–16. 10.1016/j.ypmed.2016.06.025 [PubMed: 27346757]
- Jiang N, Ling PM, 2011 Reinforcement of Smoking and Drinking: Tobacco Marketing Strategies Linked With Alcohol in the United States. *Am. J. Public Health* 101, 1942–1954. 10.2105/AJPH.2011.300157 [PubMed: 21852637]

- Kasza KA, Ambrose BK, Conway KP, Borek N, Taylor K, Goniewicz ML, Cummings KM, Sharma E, Pearson JL, Green VR, Kaufman AR, Bansal-Travers M, Travers MJ, Kwan J, Tworek C, Cheng Y-C, Yang L, Pharris-Ciurej N, van Bommel DM, Backinger CL, Compton WM, Hyland AJ, 2017 Tobacco-Product Use by Adults and Youths in the United States in 2013 and 2014. *N. Engl. J. Med* 376, 342–353. 10.1056/NEJMsa1607538 [PubMed: 28121512]
- Lemyre A, Poliakova N, Bélanger RE, 2019 The Relationship Between Tobacco and Cannabis Use: A Review. *Subst. Use Misuse* 54, 130–145. 10.1080/10826084.2018.1512623
- McKee SA, Falba T, O'Malley SS, Sindelar J, O'Connor PG, 2007 Smoking status as a clinical indicator for alcohol misuse in US adults. *Arch. Intern. Med* 167, 716–721. 10.1001/archinte.167.7.716 [PubMed: 17420431]
- McKee SA, Hinson R, Rounsaville D, Petrelli P, 2004 Survey of subjective effects of smoking while drinking among college students. *Nicotine Tob. Res* 6, 111–117. 10.1080/14622200310001656939 [PubMed: 14982695]
- McQuoid J, Thrul J, Ling P, 2018 A geographically explicit ecological momentary assessment (GEMA) mixed method for understanding substance use. *Soc. Sci. Med* 202, 89–98. 10.1016/j.socscimed.2018.02.014 [PubMed: 29518701]
- McQuoid J, Thrul J, Ozer E, Ramo D, Ling PM, 2019 Tobacco use in the sexual borderlands: The smoking contexts and practices of bisexual young adults. *Health Place* 58, 102069 10.1016/j.healthplace.2018.12.010 [PubMed: 30639203]
- Navarrete F, Rodríguez-Arias M, Martín-García E, Navarro D, García-Gutiérrez MS, Aguilar MA, Aracil-Fernández A, Berbel P, Miñarro J, Maldonado R, Manzanares J, 2013 Role of CB2 Cannabinoid Receptors in the Rewarding, Reinforcing, and Physical Effects of Nicotine. *Neuropsychopharmacology* 38, 2515–2524. 10.1038/npp.2013.157 [PubMed: 23817165]
- Nguyen N, Barrington-Trimis JL, Urman R, Cho J, McConnell R, Leventhal AM, Halpern-Felsher B, 2019 Past 30-day co-use of tobacco and marijuana products among adolescents and young adults in California. *Addict. Behav* 98, 106053 10.1016/j.addbeh.2019.106053 [PubMed: 31357072]
- Nguyen N, McQuoid J, Neilands TB, Dermody SS, Holmes LM, Ling PM, Thrul J, 2020a Same-day use of cigarettes, alcohol, and cannabis among sexual minority and heterosexual young adult smokers. *Psychol. Addict. Behav. J. Soc. Psychol. Addict. Behav* 10.1037/adb0000678
- Nguyen N, McQuoid J, Ramo D, Holmes LM, Ling PM, Thrul J, 2018 Real-time predictors of smoking among sexual minority and heterosexual young adults: An ecological momentary assessment study. *Drug Alcohol Depend.* 192, 51–58. 10.1016/j.drugalcdep.2018.07.021 [PubMed: 30212756]
- Nguyen N, Nguyen C, Thrul J, 2020b Digital Health for Assessment and Intervention Targeting Tobacco and Cannabis Co-Use. *Curr. Addict. Rep* 10.1007/s40429-020-00317-9
- Nichter Mimi, Nichter Mark, Lloyd-Richardson EE, Flaherty B, Carkoglu A, Taylor N, 2006 Gendered dimensions of smoking among college students. *J. Adolesc. Res* 21, 215–243.
- Oleson EB, Cheer JF, 2012 A Brain on Cannabinoids: The Role of Dopamine Release in Reward Seeking. *Cold Spring Harb. Perspect. Med* 2 10.1101/cshperspect.a012229
- Patton GC, Coffey C, Carlin JB, Sawyer SM, Wakefield M, 2006 Teen smokers reach their mid twenties. *J. Adolesc. Health* 39, 214–220. 10.1016/j.jadohealth.2005.11.027 [PubMed: 16857533]
- Rabin RA, George TP, 2015 A review of co-morbid tobacco and cannabis use disorders: possible mechanisms to explain high rates of co-use. *Am. J. Addict* 24, 105–116. 10.1111/ajad.12186 [PubMed: 25662704]
- Ramo DE, Liu H, Prochaska JJ, 2012 Tobacco and marijuana use among adolescents and young adults: A systematic review of their co-use. *Clin. Psychol. Rev* 32, 105–121. 10.1016/j.cpr.2011.12.002 [PubMed: 22245559]
- Schauer GL, Berg CJ, Kegler MC, Donovan DM, Windle M, 2015 Assessing the overlap between tobacco and marijuana: Trends in patterns of co-use of tobacco and marijuana in adults from 2003–2012. *Addict. Behav* 49, 26–32. 10.1016/j.addbeh.2015.05.012 [PubMed: 26036666]
- Schauer GL, Hall CD, Berg CJ, Donovan DM, Windle M, Kegler MC, 2016 Differences in the relationship of marijuana and tobacco by frequency of use: A qualitative study with adults aged 18–34 years. *Psychol. Addict. Behav. J. Soc. Psychol. Addict. Behav* 30, 406–414. 10.1037/adb0000172

- Schlienz NJ, Lee DC, 2018 Co-use of cannabis, tobacco, and alcohol during adolescence: policy and regulatory implications. *Int. Rev. Psychiatry Abingdon Engl* 30, 226–237. 10.1080/09540261.2018.1465399
- Schuster RM, Mermelstein RJ, Hedeker D, 2016 Ecological momentary assessment of working memory under conditions of simultaneous marijuana and tobacco use. *Addiction* 111, 1466–1476. 10.1111/add.13342 [PubMed: 26857917]
- Shiffman S, 2009 Ecological momentary assessment (EMA) in studies of substance use. *Psychol. Assess* 21, 486–497. 10.1037/a0017074 [PubMed: 19947783]
- Stromberg P, Nichter Mark, Nichter Mimi, 2007 Taking play seriously: Low-level smoking among college students. *Cult. Med. Psychiatry* 31, 1–24. [PubMed: 17265190]
- Subramaniam P, McGlade E, Yurgelun-Todd D, 2016 Comorbid Cannabis and Tobacco Use in Adolescents and Adults. *Curr. Addict. Rep* 3, 182–188. 10.1007/s40429-016-0101-3 [PubMed: 27175326]
- Thrul J, Gubner NR, Tice CL, Lisha NE, Ling PM, 2019 Young adults report increased pleasure from using e-cigarettes and smoking tobacco cigarettes when drinking alcohol. *Addict. Behav* 93, 135–140. 10.1016/j.addbeh.2019.01.011 [PubMed: 30710807]
- Thrul J, Kuntsche E, 2015 The impact of friends on young adults' drinking over the course of the evening--an event-level analysis. *Addiction* 110, 619–626. 10.1111/add.12862 [PubMed: 25732756]
- U.S. Department of Health and Human Services, 2014 *The Health Consequences of Smoking — 50 Years of Progress: A Report of the Surgeon General*. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, Atlanta, GA.
- Verplaetse TL, McKee SA, 2017 An overview of alcohol and tobacco/nicotine interactions in the human laboratory. *Am. J. Drug Alcohol Abuse* 43, 186–196. 10.1080/00952990.2016.1189927 [PubMed: 27439453]

### Highlights

- We investigated cigarette and alcohol and cigarette and cannabis concurrent use
- We analyzed 2,600 daily assessments collected from 126 diverse young adult smokers
- Perceived pleasure from concurrent use predicted extent of concurrent use in daily assessments
- Findings can inform tailored smoking cessation interventions

**Table 1:**

Baseline characteristics of study participants (N=126 young adult smokers)

	Number (%); M (SD)
Age (M, SD)	22.8 (2.5)
Gender	
Male	64 (50.8%)
Female	57 (45.2%)
Transgender/other	5 (4.0%)
Sexual identity	
Straight	75 (59.5%)
Sexual minority	51 (40.5%)
Race/ethnicity	
Non-Hispanic White	50 (39.7%)
Non-Hispanic Black	4 (3.2%)
Asian	25 (19.8%)
Hispanic	28 (22.2%)
Other or multi-racial	19 (15.1%)
Education	
No college or dropped out	28 (22.2%)
In college or graduated	98 (77.8%)
Number of days cigarette use in past 30 days (M, SD)	25.3 (7.3)
Number of days alcohol use in past 30 days (M, SD)	11.3 (7.6)
Number of days cannabis use in past 30 days (M, SD)	12.4 (12.1)
Change in perceived pleasure smoking; cigarettes with alcohol (1–5 scale; M (SD))	4.3 (0.8)
Change in perceived pleasure smoking; cigarettes with alcohol	
Strongly decrease	1 (0.8%)
Moderately decrease	7 (5.6%)
No Change	3 (2.4%)
Moderately increase	55 (43.7%)
Strongly increase	60 (47.6%)
Change in perceived pleasure smoking; cigarettes with cannabis (1–5 scale; M (SD)) <sup>I</sup>	3.1 (1.2)
Change in perceived pleasure smoking; cigarettes with cannabis <sup>I</sup>	
Strongly decrease	10 (11.1%)
Moderately decrease	20 (22.2%)
No Change	21 (23.3%)
Moderately increase	28 (31.1%)
Strongly increase	11 (12.2%)

Note:

<sup>I</sup>N=90

**Table 2:**

Daily diary data on substance use (N=2,600 daily diaries)

	Number (%); M (SD)
Cigarette smoking days	2,139 (82.3%)
Number of cigarettes per smoking day	5.2 (3.8)
Alcohol use days	1,004 (38.6%)
Number of drinks per alcohol use day	3.4 (2.0)
Cannabis use days	1,077 (41.4%)
Number of times cannabis use per cannabis use day	2.7 (1.7)
Cigarette and alcohol use days	891 (34.5%)
Cigarette and alcohol concurrent use on cigarette and alcohol use days (N=891)	660 (74.1%)
Extent of cigarette and alcohol concurrent use on cigarette and alcohol use days (N=891)	
None	231 (25.9%)
Some	350 (39.3%)
Most	178 (20.0%)
All	132 (14.8%)
Cigarette and cannabis use days	900 (34.6%)
Cigarettes and cannabis concurrent use on cigarette and cannabis use days (N=900)	510 (56.7%)
Extent of cigarette and cannabis concurrent use on cigarette and cannabis use days (N=900)	
None	390 (43.3%)
Some	370 (41.1%)
Most	78 (8.7%)
All	62 (6.9%)



**Table 3:**

Multilevel regression results on concurrent use of cigarettes and alcohol (N=891)

	Extent of concurrent use per day			
	Coefficient	SE	t	p-value
Change in perceived pleasure smoking cigarettes with alcohol (baseline)	0.140*	0.066	2.1	0.035
Number of cigarettes (day)	0.017	0.009	2.0	0.050
Number of alcoholic drinks (day)	0.193***	0.015	12.8	0.000
Baseline covariates				
Age	-0.015	0.023	-0.6	0.516
Gender				
Male	0.000	(-)	-	-
Female	0.295*	0.120	2.5	0.014
Transgender/other	0.222	0.280	0.8	0.428
Sexual identity (sexual minority)	-0.181	0.120	-1.5	0.131
Race				
Non-Hispanic White	0.000	(-)	-	-
Non-Hispanic Black	0.168	0.345	0.5	0.627
Asian	0.225	0.149	1.5	0.132
Hispanic	0.169	0.146	1.2	0.245
Other	-0.047	0.171	-0.3	0.781
Education (in college or graduated)	-0.016	0.140	-0.1	0.911
Constant	1.274	0.657	1.9	0.053

Note:

\*  
p < .05,\*\*  
p < .01,\*\*\*  
p < .001

**Table 4:**

Multilevel regression results on concurrent use of cigarettes and cannabis (N=900)

	Extent of concurrent use per day			
	Coefficient	SE	t	p-value
Change in perceived pleasure smoking cigarettes with cannabis (baseline)	0.136*	0.058	2.4	0.019
Number of cigarettes (day)	0.010	0.009	1.2	0.244
Number of times used cannabis (day)	0.125***	0.022	5.7	0.000
Baseline covariates				
Age	-0.029	0.025	-1.1	0.250
Gender				
Male	0.000	(-)	-	-
Female	0.015	0.145	0.1	0.916
Trans gender/other	-0.174	0.332	-0.5	0.602
Sexual identity (sexual minority)	0.081	0.140	0.6	0.565
Race				
Non-Hispanic White	0.000	(-)	-	-
Non-Hispanic Black	0.060	0.333	0.2	0.858
Asian	-0.053	0.191	-0.3	0.783
Hispanic	0.123	0.167	0.7	0.461
Other	0.029	0.182	0.2	0.871
Education (in college or graduated)	0.067	0.150	0.4	0.653
Constant	1.376*	0.670	2.1	0.040

Note:

\*  
p < .05,\*\*  
p < .01,\*\*\*  
p < .001