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Original Investigation

The Mood Boost from Tobacco Cigarettes is More Erratic with the Additions of Cannabis and Alcohol

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Abstract

Introduction: A large body of literature indicates that nicotine results in an acute mood "boost," including increased positive affect and decreased negative affect. Young adults frequently engage in polysubstance use of cigarettes with cannabis and alcohol—a trend that is likely to accelerate with the expanding legalization of cannabis. However, little is known about whether polysubstance use, defined here as combustible tobacco cigarette use within the same hour as cannabis and alcohol, is associated with changes in the nicotine mood boost. The present study aimed to address this gap.

Methods: Young adults (N = 202, 52% female, mean age = 21 years at time 1) provided ecological moments assessment (EMA) reports of cigarette use over two 7-day bursts spaced 1 year apart. In each report, participants rated mood levels before and after smoking, and indicated cannabis and alcohol use. Mixed-effects location-scale modeling simultaneously tested changes in mood levels and variability related to smoking events with cannabis and/or alcohol compared with smoking-only events.

Results: From before to after smoking, positive affect increased and negative affect decreased, on average. Overall, the additions of cannabis and/or alcohol had nonsignificant associations with these mean changes. However, polysubstance use, as well as cigarette-cannabis co-use, were each associated with significantly greater within-person variability in the positive and negative affect changes related to smoking.

Conclusions: The mood benefits associated with smoking were more erratic in the contexts of polysubstance use and cigarette-cannabis co-use. Potential implications for young adults' long-term nicotine use trajectories are discussed.

Implications: Among young adults who smoke cigarettes, the mood "boost" from smoking may be more erratic—which is to say, more likely to be either amplified or attenuated—with the additions of cannabis and alcohol together, or cannabis alone. On occasions when young adults seek out cannabis and alcohol to enhance their smoking mood boost, but instead experience a dampening effect, they might consume more nicotine, contributing over time to greater dependence. Future investigation is warranted, with particular attention to nicotine-cannabis co-use.

Introduction

The mood "boost" following nicotine use—including increased positive and decreased negative affect—features prominently in models of dependence,[1,3,4] and is cited by smokers as a primary motivation for use.[2,5] Among young adults, who are at a critical juncture with respect to nicotine use trajectories,[6] polysubstance use of nicotine with cannabis and alcohol is common.[7,8] This trend is likely to accelerate in the wake of expanding legalization of cannabis, and the growing popularity of tank-based e-cigarettes, which facilitate efficient delivery of nicotine with cannabis via a single device.[7] Such shifting patterns in the substance use landscape naturally give rise to the question: Does polysubstance use change the nicotine mood boost? Of note, polysubstance use is a general term that may include the use of multiple substances over timeframes ranging from within the same month, day, or occasion, to simultaneously within the same device. Here, we focused on combustible tobacco cigarette use that occurred on the same occasion as cannabis and alcohol use, defined by a one-hour window.

Ecological momentary assessment (EMA) provides a powerful tool for helping answer this question.[9] EMA can be used to collect data on behaviors and emotions from people in real-time as they go about their daily lives. Although these observational data do not allow for causal inference, they minimize recall bias and maximize ecological validity.[10] Moreover, by yielding relatively large numbers of observations per participant, EMA enables differentiation of within-person from between-person effects. The method is thus well-suited to capturing the associations among substance use events and emotions, which are inherently within-person processes.

EMA studies have documented robust associations between cigarette smoking and mean mood levels. For example, EMA data from a large-scale observational study of youth oversampled for novice and light smokers during adolescence and followed through young adulthood (the Social Emotional Contexts of Adolescent Smoking Patterns (SESCAP) project) showed that, on average, positive affect increased and negative affect decreased after smoking events as compared with

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random nonsmoking periods.[11–13] Such findings lent empirical support to the theoretical models and qualitative accounts of nicotine use that centrally implicated emotion regulation.[1–5]

Importantly, emotion regulation implies in part regulation of the variability in one's own mood levels, suggesting that joint modeling of both the mean and variance structures of EMA data could add meaningfully to understanding substance use patterns.[11,14] In support of this approach, within-person analyses from SECASP showed that escalations in adolescent smoking over time were associated with diminishing variability in mean positive and negative affect changes related to smoking.[11] Given that the diminishing effects of a substance with ongoing use are a core component of tolerance, these analyses provided empirical documentation of the development of tolerance among youth. Here, we propose that modeling such variability on the occasion level could add important information to understanding if polysubstance is associated with changes in the mood boost following cigarette smoking. Testing changes in mean mood levels alone would suggest whether the effects of smoking are augmented or dampened in the context of polysubstance use. Examining changes in the associated variability would indicate if the mood responses to smoking become more or less *consistent* with the additions of cannabis and alcohol. This information, in turn, could have implications for understanding the development of nicotine use trajectories among young adults. For instance, if mood responses to smoking are more erratic (i.e., more likely to be either amplified or attenuated) with polysubstance use, youth might seek out cannabis and alcohol in pursuit of greater mood boosts. On occasions when the mood response is instead dampened, youth might turn to consuming larger quantities of nicotine to achieve the desired effect—contributing, over time, to greater dependence.

Past EMA studies have linked cannabis and alcohol, examined separately, with *both* improvements and deteriorations in mood, pointing to the related possibility that polysubstance use involving cigarettes, cannabis, and alcohol could introduce greater inconsistency into the nicotine mood boost. For example, one study showed that positive affect ratings were significantly increased at first drink but decreased thereafter.[15] A review of EMA articles on cannabis use and mood returned equivocal results, which the authors speculated was due in part to varying levels of Δ9-tetrahydrocannabinol (THC) and cannabidiol (CBD) across strains.[16] THC, the primary mood-altering constitute in cannabis, appears to have dose-dependent effects on depression and anxiety: Lower doses may have ameliorative effects, whereas higher doses may increase mood symptoms.[17,18] Evidence further indicates CBD can mitigate the negative effects of THC on mood, underscoring the importance of strain composition to mood outcomes.[18,19] Past findings thus suggested that polysubstance use of nicotine with cannabis and alcohol may be associated with within-person changes in the nicotine mood boost. However, no EMA studies of which we are aware have tested this possibility. The present study aimed to address gap.

Drawing from a cohort of SECASP participants who provided EMA data in young adulthood, this study used mixed-effects location-scale modeling[11,20] to simultaneously investigate mood levels and variability surrounding smoking-only events (i.e., combustible tobacco cigarette use) as compared with polysubstance use events (i.e. cigarette use within the same hour as cannabis and alcohol). Although our primary focus was on polysubstance use, analyses also compared the smoking-only events with events of cigarette-cannabis co-use and cigarette-alcohol co-use to allow for more nuanced patterns to emerge. Consistent with prior research,[11–13] we predicted that from before to after smoking, positive affect would increase and negative affect would decrease. We did not expect to detect significant changes in these mean levels with the additions of cannabis and alcohol. In other words, we did not anticipate that polysubstance use would be associated with consistent amplification or attenuation of the nicotine mood boost. This was rooted in the findings that cannabis and alcohol have each been associated with both improvements and deteriorations in mood,[15–19] and thus detecting consistent changes in either direction seemed unlikely. However, because of this increased variation, we hypothesized that polysubstance use would be associated with significantly greater within-person variability in mean affect changes related to nicotine. That is, we expected that the nicotine mood boost would be more erratic in the presence of cannabis and alcohol.

Materials and Methods

Participants

Participants were recruited for the Social-Emotional Contexts of Adolescent Smoking Patterns (SECASP) project. The full recruitment and enrollment procedures have been detailed elsewhere.[21] In brief, ninth- and tenth-grade students from 16 Chicago-area schools were screened for smoking behaviors (at the time of screening, noncombustible devices such as vaporizers or e-cigarettes were not widely available, and thus SECASP focused on cigarette use). Those who indicated having never smoked, previously experimenting with cigarettes, currently experimenting, or regularly smoking were all eligible; recruitment was enriched for those high-risk for escalation (i.e., current experimenters and regular smokers). A total of 1263 youth provided assent, had parental permission, and completed the baseline assessment. Nine annual follow-up waves occurred, during which participants were asked to complete questionnaire measures and interviews. Retention was 90% over the first 4 waves and 80% by wave 10. Subsets of youth were invited to complete additional protocols, including EMA. The EMA data collected during young adulthood occurred over waves 5 and 6 (hereafter referred to as timepoints 1 and 2), when participants were approximately 21 and 22 years old, respectively. Participants were recruited into the young adult EMA cohort if they were at high likelihood for smoking based on earlier data; the same youth were invited to both timepoints. To test our hypotheses, the present analyses included the 202 youth who provided at least one EMA report of (a) combustible tobacco cigarette use only, and (b) cigarette use within the same hour as cannabis and/or alcohol. All youth thus contributed to at least 2 of these EMA event groups.

Procedures

At each of the 2 timepoints, participants completed a self-report questionnaire of a variety of domains including substance use, and then participated in a semi-structured interview (data from which were not included in this report). Afterwards, participants were trained by study staff to use a handheld computer for EMA. Participants carried the computer for 7 consecutive days, during which they received approximately 5 random report prompts daily. They were further asked to

initiate a report whenever they had just finished smoking a cigarette; only these self-initiated reports were included in the present analyses. All procedures were approved by the University of Illinois at Chicago Institutional Review Board.

Measures

Questionnaire Measures of Demographics and Substance Use

Annual questionnaire measures assessed demographic variables and substance use along with other psychosocial variables. The demographics included gender (0 = female, 1 = male), age, race/ethnicity, and highest level of education. The substance use measures included number of smoking days over the past week and average number of cigarettes smoked per day, and frequency of alcohol and cannabis use over the past 3 months. The response options for the alcohol and cannabis items were: zero days; once a month or less; more than once a month, but less than one a week; once or more a week, but not daily; and every day.

EMA Measures of Mood and Substance Use

In each self-initiated cigarette report, participants rated how they felt "now" using 10 adjectives each on a 10-point Likert scale, and then rated how they felt "just before" they smoked using the same adjectives and scales. Based on factor analysis and consistent with prior publications, e.g.,[12,22,23] a composite scale was created for positive affect (average scores for *happy, relaxed, cheerful, confident*, and *accepted by others*) and negative affect (average scores for *frustrated, angry, stressed, irritable*, and *sad*) for each participant at each report. Higher scores indicated more intense emotions. In each report, youth were also prompted to indicate if they had used cannabis and/or alcohol in the last hour (yes/no).

Data Analyses

A series of three-level mixed-effects location-scale models that considered observations nested within waves (time 1 or time 2) nested within participants tested the present hypotheses.[11] Mixed-effects location-scale modeling represents an extension of the basic multilevel regression analysis to include a log-linear submodel for the error (within-subject) variance, allowing for tests of the influence of covariates on both the mean and variance structures.[14,20] For each model, SAS PROC NLMIXED was used to estimate the effects of covariates on mean and within-subject variance levels of positive or negative affect; see Supplementary Appendix for sample code. The sample size (N = 202) was constant across models; full information maximum likelihood accommodated missing data. Two main models were run to test the unique effects on mood of polysubstance use (i.e., cigarette, cannabis, and alcohol use), co-use of cigarettes with cannabis only, and co-use of cigarettes with alcohol only, all as compared with cigarette-only events. One model examined mood before cigarette use, and another examined the change in mood from before to after smoking. In both cases, the positive and negative affect outcomes were run separately. Across models, gender (male or female) and timepoint (time 1 or time 2) were entered as covariates. For the occasion-varying cannabis, alcohol, and co-use indicator variables, both within-subject and between-subject effects were included in all models.[24] To account for the correlation and heterogeneity in the data, both random subject mean and within-subject variance effects were included and allowed to be correlated in the models. Additionally, all models included a random wave effect to allow for correlation of the responses from a participant within a timepoint, over and above the overall correlation within participants. The mean-level effects from each model were reported as estimated coefficients. For the effects on within-subject variance, variance ratios were calculated by exponentiating the estimated coefficients. This is similar to what is done in Poisson regression, which also features a log link function. The variance ratios thus represented the ratio of within-person variance per unit change of the variable.

Results

Descriptive statistics are presented in Table 1. Participants initiated 3,789 EMA reports of cigarette use, which were divided roughly equally across the 2 timepoints (52% came from time 1). Of the total reports, 70% represented smoking only, 4% indicated polysubstance use (i.e., cigarette use within the same hour as cannabis and alcohol), 17% were of cigarette-cannabis co-use, and 9% were of cigarette-alcohol co-use. Within the cigarette-cannabis reports, youth reported consuming cannabis most often via combustible device (i.e., bowl/pipe (48%), blunt (32%), one-hitter/dugout (14%), bong (9%), or joint (7%)), followed by vaporizer (3%), and edible (<1%); response options were not mutually exclusive. The average number of EMA reports per participant over the 2 timepoints was 18.76 (SD = 20.61). Across reports, mean positive and negative affect before smoking was 7.26 (SD = 1.89) and 3.10 (SD = 2.13), respectively. The mean change in positive affect from before to after smoking was 0.38 (SD = 1.16) indicating, on average, a 0.38 point increase following cigarette use out of the 10-point scale. The corresponding mean change in negative affect was –0.31 (SD = 1.24).

Mood Levels and Variability Before Substance Use Events

Mixed-effects location-scale modeling tested mood levels and variability before polysubstance use of cigarettes with cannabis and alcohol, and before co-use of cigarettes with each of these substances individually, as compared with before cigarette use alone (see Table 2). The purpose was to identify any floor or ceiling effects that might have driven the subsequent mood change models. In the mean model, the intercept estimates indicated that for an average female participant across timepoints, positive and negative affect ratings on a 10-point scale for before smoking were $\hat{\beta}_0$ = 6.72 (p < .0001) and $\hat{\beta}_0$ = 3.47 (p < .0001), respectively. Adjusting for between-person effects, within-person positive affect increased significantly for reports with cannabis and/or alcohol ($\hat{\beta}_{6-8}$ = 0.26–0.50, p-values < .0001), and within-person negative affect decreased significantly for cigarette-cannabis co-use ($\hat{\beta}_7$ = –0.18, p < .0001), on average. In other words, mood was generally improved prior to the use of multiple substances as compared with prior to smoking alone. However, even with the half-point increase in positive affect associated with polysubstance use (i.e., the largest estimated change on this dimension) or with the less than quarter-point decrease in negative affect associated with cigarette-cannabis co-use, there was still room for change in both scales in either direction: ($\hat{\beta}_0$ = 6.72) + ($\hat{\beta}_6$ = 0.50) = 7.22 points, on

Table 1. Descriptive Statistics for the Analytic Sample (N = 202)

Variable	n (%) or Mean (SD)	
Demographics		
Female	104 (51.49%)	
Age (years)	21.30 (0.74)	
Race/Ethnicity		
Non-Hispanic White	131 (64.85%)	
Non-Hispanic Black	29 (14.36%)	
Hispanic	32 (15.84%)	
Asian/Pacific Islander	3 (1.49%)	
Other/unknown	7 (3.47%)	
Highest Education		
Some high school	10 (4.95%)	
High school diploma/GED	42 (20.79%)	
Vocational/technical school	4 (1.98%)	
Some college	111 (54.95%)	
2-year associate degree	18 (8.91%)	
4-year bachelor degree	16 (7.92%)	
Graduate degree	1 (0.50%)	
Substance Use	**Timepoint 1 n (%) or Mean (SD)**	**Timepoint 2 n (%) or Mean (SD)**
Daily smoking rate (7-day average)	6.70 (6.52)	6.62 (5.74)
How often used cannabis (past 3 months)		
None	31 (18.67%)	29 (22.48%)
Once a month or less	26 (15.66%)	16 (12.40%)
More than once a month, less than once a week	16 (9.64%)	17 (13.18%)
One or more times a week, but not daily	41 (24.70%)	22 (17.05%)
Daily	52 (31.33%)	45 (34.88%)
How often drank alcohol (past 3 months)		
None	3 (1.81%)	2 (1.55%)
Once a month or less	7 (4.22%)	9 (6.98%)
More than once a month, less than once a week	40 (24.10%)	31 (24.03%)
One or more times a week, but not daily	108 (65.06%)	83 (64.34%)
Daily	8 (4.82%)	4 (3.10%)

Demographics data were obtained at the first timepoint. Timepoints 1 and 2 occurred 1 year apart. Substance use data were collected via retrospective, self-report questionnaires at the start of each timepoint.

average, out of the 10-point positive affect scale; and ($\hat{\beta}_0$ = 3.47) + ($\hat{\beta}_7$ = –0.18) = 3.29 points, on average, out of the 10-point negative affect scale. In the variance model, intercept estimates suggested that for an average female participant across timepoints, the variance associated with mean positive and negative affect levels before smoking was $\exp(\hat{\tau}_0)$ = 1.778 (p < .0001) and $\exp(\hat{\tau}_0)$ = 1.922 (p < .001), respectively. On the within-person level, polysubstance use was associated with approximately 40% greater variability in both positive affect ($\exp(\hat{\tau}_6)$ = 1.395, p < .05) and negative affect ($\exp(\hat{\tau}_6)$ = 1.374, p < .05). The analyses thus ruled out the possibility that floor or ceiling effects related to mood before smoking events could account entirely for any findings from the primary models testing changes in mood as a function of substance use.

Changes in Mood Levels and Variability from Before to After Substance Use Events

Mixed-effects location-scale modeling was next applied to examine mood changes related to substance use events. Table 3 presents changes in mean mood levels and variability, comparing mood post- to pre-event, for polysubstance use of cigarettes with cannabis and alcohol, and for co-use of cigarettes with each of these substances individually, as compared with cigarette use alone. In the model estimating mean mood changes, the intercept was highly significant for both positive affect ($\hat{\beta}_0$ = 0.419, p < .0001) and negative affect ($\hat{\beta}_0$ = –0.344, p < .0001). This suggested a mood boost from cigarettes when all covariates were equal to 0. Overall, the additions of cannabis and/or alcohol showed nonsignificant effects on mood levels. One exception was that cigarette-alcohol co-use was associated with a significant attenuation of the within-person increase in positive affect that followed smoking alone ($\hat{\beta}_8$ = –0.12, p < .05). Given that this effect was unexpected and an outlier in the larger pattern of nonsignificant results, not very large, and not highly significant, it may have represented a Type I error.

In the variance model, after adjusting for covariates and between-person effects, polysubstance use was associated with approximately 70-80% greater within-person variability in positive affect ($\exp(\hat{\tau}_6)$ = 1.735, p < .001) and negative affect ($\exp(\hat{\tau}_6)$ = 1.833, p < .001), on average, as compared with cigarette use alone. In other words, it appeared that the mood boost from cigarettes was less consistent in the presence of polysubstance use. Co-use of cigarettes with cannabis demonstrated a similar pattern for within-person positive affect ($\exp(\hat{\tau}_7)$ = 1.261, p < .01) and negative affect ($\exp(\hat{\tau}_7)$ = 1.295, p < .01), elevating the variability by nearly 30%. Cigarette-alcohol co-use was not associated with significant changes in variability.

Discussion

This study aimed to examine whether polysubstance use, defined here as combustible tobacco cigarette use within the same hour as cannabis and alcohol, was associated with changes in the nicotine mood boost. Drawing from a sample of young adults who were mostly light-to-moderate smokers, the primary analyses first established that after cigarette use, positive affect increased and negative affect decreased, on average, as compared with moods before smoking. These findings were consistent with existing theoretical models and qualitative accounts,[1–5] and the effect sizes that were generally comparable with prior EMA results.[11–13] In general, the mood boost was not significantly amplified or attenuated with the additions of cannabis and/or alcohol. However, there was significantly greater within-person variability in the mood changes related to polysubstance use (approximately 70–80% greater), and cigarette-cannabis co-use (approximately 30% greater), as compared with smoking alone.

That cannabis and alcohol were not significantly associated with mean mood changes related to smoking was expected in the context of existing literature. Although there has been

Table 2. Mood Levels and Variability Before Cigarette Use with Cannabis and/or Alcohol as Compared with Before Use of Cigarettes Only

	Positive affect			Negative affect		
	Estimate	**SE**	*p*	**Estimate**	**SE**	*p*
Mean model						
Intercept β_0	6.722	0.197	<.0001	3.472	0.228	<.0001
Male β_1	0.173	0.192	.37	-0.278	0.219	.21
Timepoint β_2	0.009	0.091	.92	0.135	0.119	.26
Between-subjects effects						
Polysubstance use β_3	0.444	0.821	.59	0.078	0.931	.93
Cigarettes with cannabis β_4	0.722	0.445	.11	–0.198	0.510	.70
Cigarettes with alcohol β_5	1.189	0.449	<.01	–0.738	0.532	.17
Within-subjects effects						
Polysubstance use β_6	0.502	0.121	<.0001	–0.073	0.093	.43
Cigarettes with cannabis β_7	0.320	0.056	<.0001	–0.179	0.041	<.0001
Cigarettes with alcohol β_8	0.262	0.065	<.0001	–0.030	0.059	.61
Variance model (exp.)						
Intercept τ_0	1.778	0.249	<.0001	1.922	0.359	<.001
Male τ_1	0.741	0.098	<.05	0.648	0.115	<.05
Timepoint τ_2	0.831	0.049	<.01	0.884	0.055	.05
Between-subjects effects						
Polysubstance use τ_3	3.478	2.430	.08	1.599	1.633	.65
Cigarettes with cannabis τ_4	0.988	0.333	.97	1.275	0.565	.58
Cigarettes with alcohol τ_5	0.876	0.372	.76	1.273	0.687	.66
Within-subjects effects						
Polysubstance use τ_6	1.395	0.205	<.05	1.374	0.207	<.05
Cigarettes with cannabis τ_7	1.114	0.092	.19	0.794	0.068	<.01
Cigarettes with alcohol τ_8	1.079	0.109	.45	1.022	0.103	.83

Positive and negative affect were rated on a 10-point scale. *P*-values were based on Wald statistics (Estimate/SE ~ standard normal distribution). Variance model estimates were exponentiated to represent variance ratios; the corresponding *p*-values reflected tests of variance ratios equaling one. Polysubstance use indicated events with cigarettes, cannabis, and alcohol.

minimal EMA investigation into the mood correlates of nicotine use with cannabis and/or alcohol, numerous studies have examined emotions related to cannabis or alcohol alone. Of note, one EMA study examined cigarette-alcohol co-use, and showed that drinking was associated with increased feelings of pleasure and decreased feelings of punishment from the last cigarette.[25] However, it did not address changes in mood from before to after substance use. Overall, studies have suggested that cannabis and alcohol may each be associated with either improvements or deteriorations in mood under different circumstances (e.g., cannabis strain composition, number of drinks, presence of psychiatric symptoms).[15–18] Prior findings thus suggested cannabis and alcohol likely each contributed on different occasions to either amplification or attenuation of the smoking mood boost demonstrated in the present study, potentially explaining the absence of consistent mean-level changes in either direction.

Analyses of within-person mood levels and variability prior to substance use events ruled out the possibility that floor or ceiling effects drove the nonsignificant mean-level results. Generally speaking, mood was better, and more variable, before cigarette use with other substances (i.e., cannabis and/or alcohol) as compared with moods before cigarette use alone. However, even after accounting for these increases in positive affect and decreases in negative affect, there was still substantial room to detect changes in either direction on both affect scales.

The findings that polysubstance use was associated with significantly greater within-person variability in positive and negative affect changes related to smoking represent the main contribution of this article and could have implications for understanding nicotine use behaviors and trajectories among young adults. Consistent with existing findings that cannabis and alcohol may each contribute to both improvements and deteriorations in mood, e.g.,[15–18] these results suggested the effects of smoking on mood were less consistent in the context of polysubstance use. It stands to reason that if a young person seeks out cannabis and alcohol in an effort to augment the mood effects of nicotine, and instead experiences an attenuation of their mood boost, they might consume more nicotine (and/or more of either of both of the other substances) to achieve the desired effects. Over time, this increased use could contribute to greater dependence. It should be emphasized that these conclusions are speculative, and it is possible that other reactions (e.g., extinction-like effects following unpredictable mood responses to substance use) could be more likely. However, to the extent that the erratic mood boost is akin to a variable ratio schedule—whereby reinforcement of a behavior occurs on an unpredictable schedule—high rates of responding and high resistance to extinction would be expected.[26,27]

Co-use of tobacco cigarettes with cannabis demonstrated a similar pattern of significant results as polysubstance use,

Table 3. Changes in Mood Levels and Variability from Before to After Cigarette Use with Cannabis and/or Alcohol as Compared with Before to After Use of Cigarettes Only

	Positive affect			Negative affect		
	Estimate	**SE**	*p*	**Estimate**	**SE**	*p*
Mean model						
Intercept β_0	0.419	0.069	<.0001	–0.344	0.059	<.0001
Male β_1	0.071	0.063	.26	0.048	0.054	.38
Timepoint β_2	0.006	0.041	.89	–0.042	0.038	.26
Between-subjects effects						
Polysubstance use β_3	–0.348	0.279	.21	–0.041	0.224	.85
Cigarettes with cannabis β_4	–0.148	0.160	.36	0.206	0.137	.13
Cigarettes with alcohol β_5	–0.233	0.214	.28	0.019	0.181	.92
Within-subjects effects						
Polysubstance use β_6	–0.064	0.091	.48	0.075	0.070	.28
Cigarettes with cannabis β_7	0.016	0.041	.69	0.022	0.033	.50
Cigarettes with alcohol β_8	–0.105	0.047	<.05	0.025	0.032	.44
Variance model (exp.)						
Intercept τ_0	0.938	0.153	.70	0.923	0.195	.71
Male τ_1	1.012	0.160	.94	0.871	0.179	.50
Timepoint τ_2	0.800	0.046	<.001	0.763	0.047	<.0001
Between-subjects effects						
Polysubstance use τ_3	0.609	0.489	.54	0.761	0.809	.80
Cigarettes with cannabis τ_4	1.197	0.464	.64	1.729	0.850	.27
Cigarettes with alcohol τ_5	1.972	0.870	.13	2.267	1.217	.13
Within-subjects effects						
Polysubstance use τ_6	1.735	0.251	<.001	1.833	0.287	<.001
Cigarettes with cannabis τ_7	1.261	0.100	<.01	1.295	0.106	<.01
Cigarettes with alcohol τ_8	1.155	0.108	.12	1.101	0.106	.32

Positive and negative affect were rated on a 10-point scale. Mood changes were calculated as post- to pre-event. *P*-values were based on Wald statistics (Estimate/SE ~ standard normal distribution). Variance model estimates were exponentiated to represent variance ratios; the corresponding *p*-values reflected tests of variance ratios equaling one. Polysubstance use indicated events with cigarettes, cannabis, and alcohol.

whereas cigarette-alcohol co-use did not return significant findings. This was notable in part because the cigarette-cannabis co-use events constituted a larger portion of the total EMA reports (17%) than did the cigarette-alcohol co-use events (9%), suggesting that the significant increases in variability in the cigarette mood boosts that did emerge were not simply the result of reductions in sample size. Whether cannabis was driving the polysubstance use findings—as opposed to the three substances of nicotine, cannabis, and alcohol acting synergistically in relation to mood variability—cannot be determined from the study design. Nonetheless, it is interesting to consider the nicotine-cannabis results in light of accumulating evidence that these substances may act in concert to increase dependence on one another.[28,29] If co-use of nicotine with cannabis is associated with a more erratic nicotine mood boost, young people might consume more of each product in pursuit of enhanced mood effects (e.g., using more cannabis to amplify the nicotine mood boost, and then more nicotine when the boost is instead weakened). The present findings thus point to a possible affective pathway underlying the synergistic relation between nicotine and cannabis dependence.

Study limitations warrant caution in interpreting the results. The observational SECASP study was designed primarily to examine patterns and predictors of cigarette smoking, and cannabis and alcohol use were both captured in the context of tobacco use, within 1 hour of smoking. It is possible that time effects influenced mood (e.g., moods might have differed when cannabis and alcohol were consumed at the start of the hour as opposed to concurrent with nicotine), but these nuances could not be modeled from the data. Mood responses may have also differed as a function of intoxication level, and it seems likely that participants initiated fewer reports when more severely intoxicated, potentially liming the range of experiences documented in this report. It should further be noted that cigarette smoking, in the context of cannabis use, may be driven by varying motivations including enhancement of the mood-altering effects of cannabis, as well as increased urges for tobacco.[30] Our design precluded understanding the directionality of motivations to use multiple substances in one occasion, such as whether individuals used nicotine to boost or even attenuate the effects of cannabis, or used cannabis to further accentuate the momentary mood effects of nicotine. Finally, motivations to use multiple substances may have be driven by nonmood-based reinforcers, such as social dynamics.

Despite its limitations, the study features important strengths that bolster confidence in the results. The sample represented a key demographic of young adults with respect

to polysubstance use and nicotine trajectories,[6–8] and featured a relatively large number of participants and observations. Use of EMA minimized recall bias, maximized ecological validity, and facilitated differentiation of between- from within-person effects. A state-of-the-art analytic method was employed, which replicated prior results of improved mood following smoking, while extending the findings to test changes in mood levels and within-person variability related to polysubstance use events.

In summary, this study showed that among young adult smokers, the mood benefits associated with cigarette use were more erratic with the additions of cannabis and alcohol together, or cannabis alone. These contributions are timely given the expanding legalization of cannabis and the growing popularity of tank-based e-cigarettes, both of which are likely to increase rates of nicotine-cannabis co-use in the coming years. Beyond addressing study limitations, future research might probe the social-contextual correlates of the findings; test if the findings change as a function of nicotine and/or cannabis delivery system; and examine empirically-informed mediation and moderation pathways to the mood outcomes, such as via cannabis strain compositions or baseline mental health profiles. Together with the present report, such findings would offer insight into the evolving subjective experiences of cannabis and alcohol use among young adults who use nicotine and inform targeted interventions to improve the long-term health trajectories of this important group.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interests

None declared.

Data Availability

Data cannot be shared publicly due to IRB restrictions on the initial data consent form that participants signed and the related need to maintain their privacy. The data will be shared on reasonable request to Robin J. Mermelstein.

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