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# The situational contexts and subjective effects of co-use of electronic cigarettes and alcohol among college students: an ecological momentary assessment (EMA) study

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## Abstract

**Introduction:** Understanding the co-use of e-cigarettes and alcohol, including the situational contexts and subjective effects associated with co-use in real-time is necessary for validating this behavior and informing intervention. Yet, the sparse literature has built upon retrospective data.

**Methods:** This study recruited 686 college students who were currently using e-cigarettes from three campuses in the Midwest and South of U.S in Fall 2019-Fall 2021. An on-line survey was conducted to measure e-cigarette use patterns, GPA, e-cigarette and alcohol dependence symptoms, and respiratory symptoms. A 7-day ecological momentary assessment was used to collect real-time data on e-cigarette and alcohol use, situational contexts and subjective effects.

**Results:** Frequent drinking e-cigarette users reported more high-risk use behavior including consuming 6+ drinks/occasion and simultaneous use, and reported more e-cigarettes and alcohol related dependence symptoms and respiratory symptoms, compared to infrequent/non-drinker e-cigarette users. Alcohol quantity was positively associated with e-cigarette quantity among the high frequency drinking group. This study identified important use contexts that were associated with higher e-cigarette consumption including use of menthol or fruit flavored e-cigarettes, being in a car, and the presence of others. E-cigarette use and alcohol use both increased the levels of positive affect, physiological sensation, and craving for e-cigarettes, whereas only alcohol use

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significantly decreased negative affect. No interaction effects between e-cigarette use and alcohol use were found.

**Conclusions:** The findings highlight the addiction and health risks associated with frequent co-use of e-cigarettes and alcohol, and also call for regulations on nontobacco flavorings in e-cigarette products.

### Keywords

e-cigarette; alcohol; co-use; college student; EMA

## INTRODUCTION

National survey data from the Population Assessment of Tobacco and Health (PATH) Study showed that the prevalence rate of e-cigarette use in past 30 days among college students in the United States was about 10%; and among current e-cigarette using college students, around 80% also reported alcohol use in the past 30 days (Buu et al., 2020). A recent survey (Samuolis et al., 2021) of 670 college students who had ever vaped found that about 90% of them had been involved in simultaneous use of e-cigarettes and alcohol (defined as using in close temporal proximity so the effects overlap). These data suggest a strong pattern of co-use of e-cigarettes and alcohol among U.S. college students.

The co-use of e-cigarettes and alcohol among college students may be problematic. Nicotine and alcohol can potentiate the rewarding properties of each other which may increase addiction liability for each substance (see a comprehensive review of the genetic factors and pharmacological mechanisms underlying the co-use in Cross et al., 2017). Additionally, both nicotine and alcohol consumption, and exposure to their associated cues, increase cravings for each other, making the likelihood of relapse to be higher among patients who co-use compared to those who use only one (see a comprehensive review of existing studies in Frie et al., 2021). Nicotine and alcohol co-use is also associated with greater risk for head and neck cancers, cirrhosis, pancreatitis and psychiatric comorbidity (McKee & Weinberger, 2013). Thus, college use patterns may increase the risk for dependence as well as subsequent physical and mental health issues.

Unfortunately, most of the literature on co-use of nicotine and alcohol has focused mainly on combustible cigarettes. Whether these findings are generalizable to simultaneous use of e-cigarettes and alcohol is an important research question, especially given the high prevalence of e-cigarette use among young adults (U.S. Department of Health and Human Services, 2016). In fact, e-cigarettes differ from combustible cigarettes in many different ways such as the reinforcement potential of flavors (Frie et al., 2021), the availability of various levels of nicotine concentration and flavors, and the higher levels of social acceptance of vaping and lower levels of perceived harm related to vaping compared to smoking among young adults (Buu et al., 2020; Lee et al., 2017). All of these factors may impact co-use behaviors, making it important to understand these contexts of co-use of e-cigarettes and alcohol as well as subjective effects of such use.

While some studies have examined the relationship between e-cigarette and alcohol use (Littlefield et al., 2015; Roberts et al., 2018), few studies have examined the co-use of e-cigarettes and alcohol. In a cross-sectional survey of young adult bar patrons (Thrul et al., 2019), participants reported a greater percentage of cigarette smoking compared to e-cigarette use under the influence of alcohol (64% vs. 47%), and that although participants experienced increased pleasure both from smoking and vaping while drinking, the increase in pleasure was more pronounced for cigarettes compared to e-cigarettes. A survey of adult drinkers found that a higher likelihood of co-use (measured by two scales: alcohol use leads to e-cigarette use; and e-cigarette use leads to alcohol use) was significantly associated with problematic alcohol use (Hershberger et al., 2016). However, the studies reviewed above were based on retrospective data and therefore subject to recall bias. Although a recent laboratory study found that e-cigarette puffs were positively related to subsequent alcohol sips across an ad libitum session (Hershberger et al., 2021), more research, using prospective methods, is needed to understand the contexts and subjective effects of co-use of e-cigarettes and alcohol in real-life settings.

Ecological momentary assessment (EMA) that collects behavior samples multiple times per day in the natural environment using widely accessible mobile technology is an ideal research method to study simultaneous use of e-cigarettes and alcohol, the use contexts, and the short-term effects of simultaneous use on psychological states such as mood (Buu et al., 2021). Piasecki et al. (2011) conducted an EMA study on 259 current smokers who reported frequent drinking and found that alcohol use, time of day (midnight to early morning), weekday (vs. weekend), as well as situational contexts such as others present and location (outdoor, vehicle) all increased the odds for momentary cigarette use. The same study also investigated subjective effects of the two substances on psychological states and showed that while alcohol and cigarette use both increased positive affect, only alcohol use significantly deceased negative affect. Additionally, cigarette use and alcohol use had interaction effects on participants' craving a cigarette and feeling buzzed and dizzy (Piasecki et al., 2011). This study illustrates the important understanding of co-use patterns that can be gleaned from EMA studies and raises the question of whether such findings would replicate among persons who use e-cigarettes.

The present study aims to fill the knowledge gaps by conducting an EMA study with college students who currently used e-cigarettes to investigate co-use of e-cigarettes and alcohol in real time and real life. E-cigarette users who frequently drank alcohol were compared with those who did not frequently use alcohol in terms of e-cigarette use patterns, high-risk alcohol use, e-cigarette and alcohol dependence, and respiratory symptoms. Three hypotheses were tested. First, high frequency drinking e-cigarette users were hypothesized to be involved in high-risk use of both substances and have greater e-cigarette dependence and respiratory symptomatology than low frequency drinking e-cigarette users. Second, alcohol quantity was hypothesized to be positively associated with e-cigarette quantity among the high frequency drinking group, even after adjusting for the effects of use contexts. Third, simultaneous use of e-cigarettes and alcohol was hypothesized to enhance the effects of each single substance on psychological states including positive affect, negative affect, physiological sensation, and craving.

# METHODS

## Study Sample

This study recruited 686 participants from one 4-year college campus in Indiana and two campuses in Texas based on five inclusion criteria: (1) e-cigarette use at least once per week in the last 4 weeks; (2) no intention to quit e-cigarette use in the next 30 days; (3) 1st to 3rd year undergraduates; (4) ownership of a smartphone; and (5) using a cartridge system, tank system, or pod mod e-cigarette. Study flyers were distributed to the student populations through email listservs, social media, online classified advertising sites, and bulletin boards in campus buildings. We also distributed flyers in person through tabling events on campus and gained permission from some instructors to give a brief presentation in their undergraduate classes. The recruitment period was from Fall 2019 to Fall 2021. To complete the longitudinal assessment of each participant in four consecutive semesters, the data collection period covered Fall 2019 to Spring 2023.

## Study Design & Procedure

This longitudinal EMA study assessed participants' e-cigarette and polysubstance use through an on-line survey and 7-day EMA via a smart phone app in each of four consecutive semesters. The study protocol was approved by the Institutional Review Board (IRB) of the University of Texas Health Science Center at Houston (HSC-SPH-19-0391). Every eligible college student who signed up for the study was scheduled an in-person baseline assessment during which he/she provided informed consent, filled out demographic information, completed a lifetime measure of substance use, and received a training session on EMA protocol and a payment of $20. All the assessments were self-administered. The participant was also offered the opportunity to earn an extra $20 by providing a saliva cotinine sample. Due to public health concerns related to the COVID pandemic, some of the baseline assessments were conducted virtually; the bio-sample data collection was suspended from March 2020 to May 2022 and was later resumed in follow-up assessments to validate self-report data.

After the baseline assessment, an email was sent to the participant with a link to an on-line survey ($20 for participation) that measured average/typical consumption of substances and related outcomes. The survey also inquired about the student's typical wake-up time and bedtime on weekdays and weekends that determined the individualized period of computer-initiated prompts during the 7-day EMA data collection, which started on the following day. The same procedure of administering the on-line survey and EMA was repeated for each of the following 3 semesters. In this paper, we restricted our analyses to the on-line survey and EMA data from the semester during which each student was initially recruited to ensure participants were vaping at least once per week.

## Measures

**Demographic background.—**At baseline assessment, participants were asked about their age (years), biological sex (female or male), Hispanic ethnicity (Y/N), and race including White, Black, Asian, and other races.

**Academic and health outcomes.—**In the on-line survey, participants self-reported their GPA in the past semester as a measure of their academic performance. Three health outcomes included in the analysis were measured by the following well-validated scales: (1) the 10-item Penn State Electronic Cigarette Dependence Index (PS-ECDI; Foulds et al., 2015) for e-cigarette dependence (e.g., Did you feel nervous, restless, or anxious because you couldn't use and electronic cigarette?) with the score range of 0-20; (2) the 10-item Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) for alcohol problems (e.g., During the past year, how often have you had a feeling of guilt or remorse after drinking?) with the score range of 0-40; and (3) the 8-item American Thoracic Society Questionnaire (ATSQ; Comstock et al., 1979) that assesses chronic bronchitis symptoms found in adolescent who used e-cigarettes and cigarettes (Cassidy et al., 2015; McConnell et al., 2017) with the score range of 8-40 (see the symptoms listed in Table 1). Higher scores on the PS-ECDI, AUDIT, and ATSQ indicate higher levels of symptomatology.

**E-cigarette use patterns and motivation to use.—**In the on-line survey, participants responded to a retrospective e-cigarette consumption measure about the quantity/frequency, device features, nicotine concentration, flavor, co-use, situational contexts, and reasons of use in the past 30 days, which could be associated with e-cigarette dependence (Wong et al., 2019).

**EMA measures.—**Three types of EMA data were collected via a smartphone app: random prompts, participant-initiated event reports, and end-of-day summary reports. *Random prompts* were initiated by the study app 5 times per day throughout participants' waking hours and assessed (a) current positive affect (excited, enthusiastic), negative affect (sad/unhappy, anxious/worried/stressed, angry/irritated), e-cigarette craving (thinking about vaping, want to use an e-cigarette), and physiological sensation (buzzed/dizzy) on a 7-point scale; and (b) whether they have used e-cigarettes or alcohol in the past hour (Y/N). *Participant-initiated event reports* – one in the morning (wake-up to 1 pm) and the other in the afternoon (1-8:30 pm) – assessed the most recent e-cigarette use event including the quantities of e-cigarette use (the number of puffs) and alcohol use (the number of standard drinks), the flavor (tobacco, menthol, fruit, etc.), and contexts of use including where (residence, campus-outdoor, campus-indoor, car, and other), with whom (alone, with others vaping, with others smoking, with others drinking, with others not vaping/smoking/drinking). *End-of-day summary reports* were initiated by the participant before bedtime to summarize e-cigarette and alcohol consumption and stressful events during the day (these data were not analyzed in this paper). The system sent a reminder for each of the participant-initiated reports: morning (60-100 minutes after the wake-up time), afternoon (2-4:10 pm), and end-of-day (60-75 minutes before the bedtime). Participation in each of the above assessments was rewarded with $2. To encourage high compliance, we offered an entry to win an Amazon gift card of $50 as a "bonus payment" if the participant completed more than 80% of all EMA reports during the 7-day period in each semester. The chance of winning was 5%.

### Statistical Analysis

Frequent drinkers (i.e., e-cigarette users who reported using alcohol at least 2 times a week) were compared with infrequent/non-drinkers in terms of demographics, academic performance, e-cigarette use patterns, reasons for e-cigarette use, high-risk alcohol use, dependence symptoms, and respiratory symptoms using two-sample t tests or Chi-square tests. These analyses tested the first hypothesis that the high frequency drinking e-cigarette users would be involved in high-risk use of both substances and have greater e-cigarette dependence and respiratory symptomatology than low frequency drinking e-cigarette users.

Analyses of EMA data were used to test the second and third hypotheses, using only data from frequent drinkers because the co-use behaviors were more likely to be captured by the 7-day EMA. To test the second hypothesis that alcohol quantity would be positively associated with e-cigarette quantity, a generalized linear mixed model (GLMM) with the log link function (Poisson) was used to model the number of puffs drawn on an e-cigarette as a function of the number of standard drinks, adjusting for the effects of e-cigarette flavor, when, where, and presence of other(s), based on data from the participant-initiated event reports. Three binary covariates were created for tobacco, menthol and fruit flavors due to their higher prevalence or addictive potential. A random intercept was employed to handle the correlation among event reports within each participant. The GLMM can deal with missing assessments under the missing-at-random assumption (Diggle et al., 2002). The analyses were carried out using the R package: lme4 (Bates et al., 2015), with the *p*-values of fixed effects calculated by the R package: lmerTest (Kuznetsova et al. 2017).

Data on psychological states as well as e-cigarette and alcohol use within the past hour reported in the random prompts of EMA were used to test the third hypothesis that simultaneous use of e-cigarettes and alcohol would enhance the effect of each single substance on psychological states including positive affect, negative affect, craving, and physiological sensation. The mean of the corresponding items was calculated as the composite score for each psychological state. Because the sample distributions of these composite scores were right-skewed, they were log-transformed. A GLMM with the identity link function (linear) and a random intercept was used to model each of these log-transformed variables as a function of e-cigarette use (binary), alcohol use (binary), and their interaction.

## RESULTS

Table 1 shows the descriptive statistics for the 325 frequent alcohol drinkers and 361 infrequent/non-drinkers (only 4% were non-drinkers). There was no difference among frequent and infrequent/non-drinkers in the percentage who also smoked combustible cigarettes (13.8 vs. 12.2%); dual users in the two groups did not significantly differ on smoking frequency or cigarette dependence. The average age was about 20 in both drinker groups. About 78% of the entire sample did not reach the legal drinking age of 21. Among frequent drinkers, the percentage of Whites was higher (79.7 vs. 61.2%) and the percentage of Hispanic was lower (9.8 vs. 15.2%) compared to infrequent/non-drinkers. The two drinker groups had about the same average GPA: 3.44 (20% were freshmen who reported their GPA of the previous semester in high school). In terms of e-cigarette use

patterns, frequent drinkers tended to use a higher concentration level of nicotine (48.03 vs. 45.43 mg/ml), use alone less frequently (45.62 vs. 56.33%), and spend more money on e-liquid/cartridge (69.11 vs. 54.58 dollars). While a higher percentage of frequent drinkers used a menthol-flavored e-cigarette (75.1 vs. 64.5%), fewer of them used a fruit-flavored one (52.6 vs. 65.9%). When asked about most important reasons for e-cigarette use, frequent drinkers tended to endorse being "hooked" (49.5 vs. 39.8%), whereas a lower percentage reported "regular cigarette use is not permitted" (2.8 vs. 6.5%) or "to experiment" (15.4 vs. 22.4%). Further, frequent drinkers reported consuming six or more drinks on one occasion more frequently (2.16 vs. 1.04) and spending more time on simultaneous use of e-cigarettes and alcohol (45.60 vs. 22.69%).

Consistent with the first hypothesis, frequent drinkers had higher levels of e-cigarette dependence (PS-ECDI: 9.96 vs. 9.13), albeit both groups demonstrated medium dependence, and alcohol problems (AUDIT: 12.60 vs. 6.81), with the frequent drinkers' AUDIT scores indicating harmful or hazardous drinking. Frequent drinkers also reported higher levels of respiratory symptomatology (see Table 1). Such group differences in respiratory symptomatology were unlikely confounded by combustible cigarettes.

Among the 325 frequent drinkers, 269 (83%) provided some participant-initiated event reports in EMA and were all included in the analysis. The median compliance rate was 71% (out of 14 prompts); the rate was not associated with sex, age, race, or ethnicity. The regression coefficients were exponential-transformed to facilitate interpretation (i.e., incident risk ratio [IRR]). Consistent with the 2$^{nd}$ hypothesis, higher alcohol quantity was associated with higher e-cigarette quantity: for each additional alcohol drink consumed, the number of puffs was expected to increase by 4%. See Table 2. Although there was no difference in e-cigarette consumption between the weekday and weekend, e-cigarette quantity in the morning was only 48% of that in the afternoon. While a tobacco flavor was not associated with e-cigarette quantity, a menthol flavor and a fruit flavor increased e-cigarette quantity by 34% and 23%, respectively. In comparison to being alone, the presence of others was associated with higher e-cigarette consumption. Particularly, being companied by others vaping/smoking/drinking increased the number of puffs by 25%. Although participants consumed about the same quantity of e-cigarettes in their residence or on campus (both outdoor and indoor), e-cigarette quantity was about 11% higher in the car than in the residence.

Among the 325 frequent drinkers, 256 (79%) responded to some random prompts in EMA and were all included in the analysis. The median compliance rate was 40% (out of 35 prompts); the rate was not associated with sex, age, race, or ethnicity. None of the interactions between e-cigarette and alcohol use were significant, therefore, they were not included in the final models. See Table 3. The regression coefficients were exponential-transformed (i.e., $\exp(\beta)$) to facilitate interpretation because the psychological state outcomes were log-transformed. E-cigarette use and alcohol use increased positive affect by 17% and 28%, respectively. Additionally, positive affect tended to be higher in the afternoon and evening compared to the morning. Although using alcohol may alleviate negative affect by 13%, using e-cigarettes did not have a significant effect. In general, the level of negative affect was lower in the weekend. Moreover, e-cigarette use and alcohol use both

significantly increased the level of physiological sensation by 13% and 39%, respectively. In general, the level of physiological sensation was higher in the weekend. Furthermore, e-cigarette use and alcohol use increased the level of craving for e-cigarettes by 22% and 12%, respectively. The level of craving also tended to be higher in the evening than in the morning.

## DISCUSSION

This study has made a unique contribution by investigating three important research hypotheses about co-use of e-cigarettes and alcohol among college students. Consistent with the first hypothesis, this study showed that frequent drinking e-cigarette users tended to have more high-risk behaviors, including consuming six or more drinks on one occasion, simultaneous use of e-cigarettes and alcohol, more e-cigarettes and alcohol dependence symptoms, and more respiratory symptoms, compared to the infrequent/non-drinker counterparts. As predicted by the second hypothesis, our EMA data analysis found that alcohol quantity was positively associated with e-cigarette quantity among the high frequency drinking group, even after adjusting for the effects of use contexts. The EMA results also identified important use contexts that were associated with a higher level of consumption of e-cigarettes, including use of menthol or fruit flavored e-cigarettes, afternoon (vs. morning), being in a car, and the presence of others (especially with others vaping/smoking/drinking). Although our finding of nonsignificant interaction effects between e-cigarette and alcohol use on psychological states did not support the third hypothesis that simultaneous use of the two substances would enhance the effect of each single substance, we did find that e-cigarette use and alcohol use both increased the levels of positive affect, physiological sensation, and craving for e-cigarettes (i.e., significant main effects). In general, the magnitude of the alcohol effect on psychological states was greater than that of the e-cigarette effect with the exception of craving for e-cigarettes.

Consistent with the finding of a previous EMA study on co-use of cigarettes and alcohol (Piasecki et al., 2011), our study showed that while e-cigarette use and alcohol use both increased positive affect, only alcohol use significantly decreased negative affect. Yet, unlike that study, we did not find statistically significant interaction effects between e-cigarette use and alcohol use on craving for e-cigarettes or feeling buzzed and dizzy. In fact, a more sophisticated analysis of the EMA data from the same prior study (Piasecki et al., 2012) showed that smoking was associated with enhanced buzz and excitement when estimated blood alcohol concentration (BAC) was high and *descending*, suggesting that cigarettes may *extend* the stimulant effects of alcohol beyond the BAC peak. Thus, potential interactions between smoking and drinking may depend on the order of substance use, the quantity of alcohol use, and the latency since completion of the first drink. In our random prompt EMA, we only collected binary information about e-cigarette use and alcohol use in the past hour to reduce participant burden, so our nonsignificant interaction effects may be due to measurement issues as well as differences between combustible cigarettes and e-cigarettes. Non-nicotine constituents in combustible and electronic cigarettes may have complex pharmacological interactions with nicotine and alcohol, making the subjective effects of co-use of e-cigarettes and alcohol different from those of co-use of combustible cigarettes and alcohol. This would be consistent with results from Thrul et al. (2019) who

found the increase in pleasure while drinking alcohol was more pronounced for cigarettes compared to e-cigarettes.

This EMA study has identified some important situational contexts that may inform interventions for e-cigarette use among college students who drink alcohol frequently. The finding that higher consumption of e-cigarettes was more likely to occur when there were companions is in line with college students' lifestyle. Previous studies have documented that college students consumed more e-cigarettes (and alcohol) when others were around or during parties likely due to the perceived positive social effect of e-cigarettes (Wallace et al., 2018; Samuolis et al., 2021) and compromised normative perception about substance use (Brooks-Russell et al., 2014; Neighbors et al., 2006). Future e-cigarette health communication campaigns may target these situational contexts and associated perceptions (Escoto et al., 2021).

Another situational context that was associated with higher consumption of e-cigarettes was vaping in a car (rather than in residence or on campus), possibly due to the tobacco-free policies implemented in the universities where we recruited our study participants. While a tobacco-free car legislation has also been implemented by some states, localities, and college campuses, effective enforcement has been difficult (e.g., Patel et al., 2018). Given that harmful substances have been identified in secondhand e-cigarette aerosol (Su et al., 2021), educational efforts to enhance college students' perception about e-cigarettes' risk to bystanders are warranted to reduce in-car vaping.

This study also identified menthol or fruit flavors to be important use contexts for higher e-cigarette consumption. These flavors may facilitate e-cigarette use because of their potential effects of reducing bitterness and harshness of nicotine and e-cigarette aerosol (Leventhal et al., 2020). Furthermore, flavored e-cigarettes were shown to be associated with lower harm perception among young adults (Chen et al., 2018), and yet contain chemicals that may impose health risks (Gerloff et al., 2017; Omaiye et al., 2019). The U.S. Food and Drug Administration (FDA) has implemented a flavor ban on tank- and cartridge-based e-cigarettes except for menthol and tobacco flavors (the menthol flavor is currently in the process of being regulated). However, the disposable e-cigarettes popular among young people are not currently restricted due to FDA's narrow definition of a cartridge (Tackett et al., 2020). Our findings echo the calls for closing the loophole to further restrict non-tobacco flavors of disposable e-cigarettes (Dai & Hao, 2022).

Some limitations of this study are important to note. First, the online survey and EMA data were self-reported and were subject to biases. Second, in our random prompt EMA questions, we collected data on e-cigarette and alcohol use statuses in the past hour to reduce participant burden, so the order and quantity of e-cigarette and alcohol use could not be determined, which precluded the inference of whether e-cigarettes extended the stimulant effects of alcohol or the other way around. Third, the participant-initiated EMA questions captured the most recent e-cigarette use event that did not necessarily reflect the event at the moment nor all events happening in a day (1 report in the morning and 1 in the afternoon). Yet, it allowed us to track compliance and avoid the risk of encouraging use or overreporting. Fourth, although our study sites covered both urban and rural settings, the

findings still cannot be generalized to the entire college student population in the U.S. Fifth, the COVID-19 pandemic tended to limit the participants' social lives especially during Fall 2020-Spring 2021, which may have impacted their substance use or compliance with EMA.

In sum, this research provides the first in-depth look at the contexts of vaping and drinking alcohol among college students, using prospective, real-time data collected in a real-life setting. These data provide insight into differences between e-cigarette users who do and do not drink frequently as well as the different use contexts and differential associations the two substances have on affective experiences among frequent drinking vapers (i.e., drinking and vaping are associated with increased positive affect but only alcohol is associated with decreased negative affect). These data provide key insight into how college students are using e-cigarettes and alcohol and how such patterns may support or interfere with cessation.

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**Table 1.**

The differences between e-cigarette using college students who drank alcohol frequently and those who did not.

| | Frequency (%) or mean (standard deviation) | | |
|---|---|---|---|
| **Variables** | **Frequent drinkers [a] (N=325)** | **Infrequent/non- drinkers (N=361)** | **p-value** |
| **Demographics & academic performance** | | | |
| Age | 19.79 (1.21) | 19.85 (1.47) | 0.528 |
| Male | 154 (47.4%) | 181 (50.1%) | 0.520 |
| Race: White | 259 (79.7%) | 221 (61.2%) | <0.001 |
| Black | 10 (3.1%) | 23 (6.4%) | |
| Asian | 37 (11.4%) | 79 (21.9%) | |
| Other race | 19 (5.8%) | 38 (10.5%) | |
| Hispanic | 32 (9.8%) | 55 (15.2%) | 0.045 |
| GPA | 3.44 (0.44) | 3.44 (0.43) | 0.890 |
| **E-cigarette use patterns in past 30 days** | | | |
| Number of days vaping | 25.31 (7.14) | 24.92 (7.56) | 0.498 |
| Number of times vaping per day | 1.54 (0.62) | 1.55 (0.81) | 0.947 |
| Using pod (instead of tank or cartridge) | 264 (81.2%) | 291 (82.7%) | 0.699 |
| Concentration level of nicotine (mg/ml) [b] | 48.03 (13.48) | 45.43 (15.73) | 0.033 |
| Using tobacco flavor | 28 (8.6%) | 28 (8.0%) | 0.863 |
| Using menthol flavor | 244 (75.1%) | 227 (64.5%) | 0.004 |
| Using fruit flavor | 171 (52.6%) | 232 (65.9%) | 0.001 |
| Number of minutes to 1st puff after waking up | 32.85 (29.24) | 36.21 (29.70) | 0.140 |
| Percent of e-cigarette use alone (without company) | 45.62 (25.40) | 56.33 (25.95) | <0.001 |
| How difficult to refrain in forbidden places (1-5) | 2.67 (1.23) | 2.50 (1.10) | 0.051 |
| Dollars spent on e-liquid/cartridge past month | 69.11 (83.36) | 54.58 (46.77) | 0.005 |
| **Most important reasons for e-cigarette use** | | | |
| To help quit regular cigarettes | 16 (4.9%) | 22 (6.2%) | 0.560 |
| Regular cigarette use is not permitted | 9 (2.8%) | 23 (6.5%) | 0.034 |
| To have good time with friends | 152 (46.8%) | 147 (41.8%) | 0.217 |
| To relax or relieve tension | 224 (68.9%) | 226 (64.2%) | 0.223 |
| Look cool | 39 (12.0%) | 52 (14.8%) | 0.345 |
| Boredom, nothing else to do | 132 (40.6%) | 140 (39.8%) | 0.885 |
| Tastes good | 102 (31.4%) | 130 (36.9%) | 0.150 |
| To experiment, to see what it’s like | 50 (15.4%) | 79 (22.4%) | 0.025 |
| To feel good or get high | 120 (36.9%) | 107 (30.4%) | 0.086 |
| Hooked | 161 (49.5%) | 140 (39.8%) | 0.013 |
| **Alcohol & combustible cigarette use** | | | |
| Consuming 6+ drinks on 1 occasion (0-4) | 2.16 (0.83) | 1.04 (0.71) | <0.001 |
| Percent of e-cigarette use while co-using alcohol | 45.60 (28.61) | 22.69 (26.01) | <0.001 |
| Dual use of combustible cigarettes | 45 (13.8%) | 42 (12.2%) | 0.597 |
| **Dependence symptoms** | | | |

| | Frequency (%) or mean (standard deviation) | | |
|---|---|---|---|
| **Variables** | **Frequent drinkers [a] (N=325)** | **Infrequent/non- drinkers (N=361)** | **p-value** |
| PS-ECDI (e-cigarette dependence) | 9.96 (4.74) | 9.13 (5.06) | 0.029 |
| AUDIT (alcohol problems) | 12.60 (4.88) | 6.81 (3.79) | <0.001 |
| **Respiratory symptoms** (1-5) | | | |
| Coughing first thing in the morning | 1.76 (0.96) | 1.52 (0.81) | 0.001 |
| Cough frequently throughout the day | 2.09 (1.06) | 1.90 (0.99) | 0.014 |
| Wheezing | 1.36 (0.74) | 1.29 (0.64) | 0.198 |
| Shortness of breath when walking | 1.82 (1.03) | 1.74 (0.99) | 0.329 |
| Shortness of breath exercise/walking upstairs | 2.23 (1.16) | 2.15 (1.21) | 0.346 |
| Phlegm/mucous when coughing | 1.65 (1.00) | 1.47 (0.89) | 0.013 |
| Pain or tightness in the chest | 1.69 (0.87) | 1.51 (0.81) | 0.006 |
| Get very tired in a short time | 2.10 (1.13) | 1.97 (1.20) | 0.177 |

[a] E-cigarette users who reported using alcohol at least 2 times a week.

[b] Only 6 participants (<1%) reported using the concentration level of 0 mg/ml.

**Table 2.**

Generalized linear mixed model with the log link function (Poisson) for examining the effects of alcohol quantity and e-cigarette use contexts on the number of puffs taken during vaping events among e-cigarette users who used alcohol at least 2 times a week (N=269).

| | Coefficient (Standard error) | Incident risk ratio (IRR) | *p*-value |
|---|---|---|---|
| Intercept | 1.683 (0.064) | 5.381 | <0.001 |
| **Alcohol quantity** | 0.042 (0.004) | 1.042 | <0.001 |
| **When** | | | |
| EMA day (1st-7th) | 0.009 (0.004) | 1.009 | 0.015 |
| Weekend | −0.009 (0.015) | 0.991 | 0.539 |
| Morning (reference: afternoon) | −0.727 (0.016) | 0.484 | <0.001 |
| **Flavor** | | | |
| Tobacco flavor | −0.009 (0.054) | 0.991 | 0.861 |
| Menthol flavor | 0.295 (0.035) | 1.343 | <0.001 |
| Fruit flavor | 0.209 (0.030) | 1.233 | <0.001 |
| **Company** (reference: alone) | | | |
| With others not using tobacco/alcohol | 0.090 (0.029) | 1.094 | 0.002 |
| With others vaping/smoking/drinking | 0.220 (0.019) | 1.246 | <0.001 |
| **Where** (reference: residence) | | | |
| Campus – outdoor | 0.026 (0.041) | 1.027 | 0.515 |
| Campus – indoor | −0.031 (0.043) | 0.969 | 0.470 |
| Car | 0.108 (0.031) | 1.114 | <0.001 |
| Other places | −0.173 (0.045) | 0.842 | <0.001 |

Note: This set of analysis was based on the participant-initiated event reports (in the morning and afternoon) in the EMA data.

**Table 3.**

Generalized linear mixed models with log-transformed outcomes for examining e-cigarette use and alcohol use effects on psychological states among e-cigarette users who used alcohol at least 2 times a week (N=256).

| | Positive affect | | Negative affect | | Physiological sensation | | Craving | |
|---|---|---|---|---|---|---|---|---|
| | $\beta$(se) | exp($\beta$) | $\beta$(se) | exp($\beta$) | $\beta$(se) | exp($\beta$) | $\beta$(se) | exp($\beta$) |
| Intercept | 0.870 (0.032) | 2.387*** | 0.672 (0.029) | 1.959*** | 0.278 (0.031) | 1.321*** | 0.818 (0.035) | 2.265*** |
| **Substance use in past hour** [a] | | | | | | | | |
| Using e-cigarette | 0.157 (0.017) | 1.170*** | −0.012 (0.016) | 0.988 | 0.120 (0.018) | 1.128*** | 0.200 (0.017) | 1.221*** |
| Using alcohol | 0.249 (0.023) | 1.283*** | −0.142 (0.022) | 0.868*** | 0.327 (0.024) | 1.386*** | 0.115 (0.024) | 1.121*** |
| **When** | | | | | | | | |
| EMA day (1st-7th) | −0.009 (0.003) | 0.991** | −0.003 (0.003) | 0.997 | −0.010 (0.003) | 0.990** | −0.014 (0.003) | 0.986*** |
| Weekend | 0.022 (0.013) | 1.023 | −0.031 (0.013) | 0.970* | 0.031 (0.014) | 1.031* | 0.016 (0.014) | 1.016 |
| Afternoon[b] | 0.113 (0.016) | 1.120*** | −0.008 (0.015) | 0.992 | −0.018 (0.017) | 0.982 | 0.031 (0.017) | 1.032 |
| Evening[b] | 0.076 (0.017) | 1.079*** | −0.008 (0.016) | 0.992 | 0.019 (0.018) | 1.020 | 0.043 (0.017) | 1.044* |

Note: This set of analysis was based on the random prompts in the EMA data.

[a] None of the interaction effects of e-cigarette and alcohol use were significant so they were not included in the models.

[b] The reference is morning.

* p<0.05;

** p<0.01;

*** p<0.001