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Initiation of vaporizing cannabis: Individual and social network predictors in a longitudinal study of young adults

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Abstract

Background—A trend has recently emerged of individuals using electronic nicotine delivery systems (ENDS) or similar devices to vaporize cannabis, either in the form of high-potency THC concentrates or cannabis plant material. Peer use is central to the adoption of substance use behaviors in young adulthood, but little is known about peer influence for initiating cannabis vaping.

Methods—A longitudinal investigation of first-year college students (N = 1,313) using social network methods was conducted to determine the prevalence of vaping cannabis, differences in networks between individuals who initiate vaping cannabis, and predictors of initiation of vaping cannabis across two time points. The surveys were available for two weeks beginning in the sixth week of each semester.

Results—We found that 9.4% vaped in their lifetime but not since the first survey, 7.5% vaped in their lifetime and since the first survey, and 5.9% reported vaping cannabis at the second survey. Lifetime cannabis use, lifetime ENDS use, and number of peers who initiated vaping cannabis from Time 1 to Time 2 were significantly associated with increased odds of the initiation of vaping cannabis; the number of any-cannabis-using or any-ENDS-using peers was not associated with increased odds of initiating vaping cannabis.

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Conflict of Interest

No conflict declared.

Contributors

RNC generated the initial idea for the analysis reported in the manuscript and prepared the manuscript first draft. MKM generated the analysis plan, completed all logistic regression analyses and generated tables and figures, as well as contributing greatly to manuscript drafting and editing and approving the final manuscript. GD served as project coordinator on the study, aided in data analysis and interpretation, and edited drafts of the manuscript. SB aided in data analysis and edited and approved the final draft of the manuscript. NPB was the principal investigator of the grant which funded this study, provided feedback on analysis strategies, and edited and approved the final manuscript. All authors contributed to and approved of the final version of the manuscript.

Conclusions—Individuals with the greatest risk of initiation of vaping cannabis during the first year of college are those with a prior history of other cannabis use and ENDS use and who have peers in their network who initiate cannabis vaping.

Keywords

Cannabis; ENDS; Vaping; Young Adults; Peer Networks

1. Introduction

The proliferation of electronic nicotine delivery systems (ENDS) has introduced a generation of young people to a new method of ingesting nicotine that does not require combustion. These devices, which heat a liquid that typically contains nicotine and flavorings to an inhalable aerosol, have become popular among young people (Johnston et al., 2017). As of 2015, ENDS (also called e-cigarettes or “vapes”) were the most commonly used tobacco product by youth (Singh et al., 2016). The long-term health effects of these products are currently unknown, and more disturbingly, there is evidence that use of these products by never-smoking adolescents increases the risk of initiating traditional cigarette smoking in adolescents and young adults (Leventhal et al., 2015; Loukas et al., 2018; Soneji et al., 2017; Spindle et al., 2017).

As young people have adopted these devices for vaping nicotine, a growing trend has emerged in which individuals use their ENDS to ingest cannabis via THC-containing wax (e.g., ‘dabs’; Daniulaityte et al., 2015), oil, or by using similar portable devices that heat ground cannabis plant material without burning it to produce a vapor (Giroud et al., 2015; Kenne et al., 2017; Loflin and Earleywine, 2014). In both adults and adolescents, prevalence of having ever vaped cannabis among ever-users of e-cigarettes and ever-users of cannabis was about 18%, and a strong predictor of this behavior was frequent use of ENDS. In adults, a relationship was found between greater rates of impulsivity and ever-vaping of cannabis (Morean et al., 2015; Morean and L’Insalata, 2017). In a young adult general population sample of both smokers and non-smokers, 29% had ever vaped cannabis, and this behavior was associated with male gender, nicotine-containing ENDS use, and heavier current cannabis use (Jones et al., 2016). Recent studies have shown that about 7– 29% of college students have used an e-cigarette for cannabis or other non-nicotine drug vaping (Frohe et al., 2017; Kenne et al., 2017). However, these studies were cross-sectional, which does not allow for an investigation into the stability of this behavior over time or to study predictors of initiation.

Traditional vaporizers for cannabis, which heat the plant matter itself without burning it, have existed on the market for several years (Hazekamp et al., 2006). However, they have not garnered as much attention as more novel forms of vaping cannabis, which typically require a processed marijuana concentrate such as wax, oil, or liquid that can be used in ENDS (Daniulaityte et al., 2015). Unlike modern vapes, traditional vaporizers were generally larger, tabletop devices that were not portable and were typically more expensive relative to the more popular joints, pipes, and blunts, making them less appealing to young people (Johnson et al., 2016). Recently, however, in the wake of increasing of ENDS use

among youth, pen-style vaporizers which require only ground cannabis buds have become more popular. Whereas vaping ground plant material has been shown to reduce respiratory symptoms relative to traditionally smoking cannabis (Earleywine and Barnwell, 2007), there is debate about whether vaping cannabis via wax or oil in an ENDS does in fact meaningfully reduce respiratory harms (Budney et al., 2015; Tashkin, 2015). Further, use of cannabis oil that has been extracted via butane heating can contain very high amounts of THC, and use of this type of oil has been associated with greater reports of cannabis-related harms in young people (Meier, 2017; Chan et al., 2017). Recent studies suggest that dual cannabis and ENDS use is associated with increased risk of heavier use of both cannabis and ENDS in adolescents, though the authors were not able to report whether the ENDS devices were being used to vape nicotine or cannabis (Dai and Hao, 2017). Thus, concern is mounting that ENDS and similar products may not only provide a gateway to cigarette smoking but also to increased cannabis use among young people and the potential for exposure to more harmful THC concentrations (Borodovsky, 2017; Blundell et al., 2017).

Vaping cannabis may become increasingly popular for youth relative to smoked cannabis for a number of reasons. One such reason is by providing a discreet method of administration that can be used in places where smoking of any kind is not allowed, as vaping cannabis produces very little visible vapor, the aroma is greatly reduced relative to traditional smoking, and vape pens do not resemble traditional joints or bowls used for smoking cannabis (Malouff et al., 2014). Further, vaping cannabis may be perceived as less harmful than smoking cannabis by burning it through a pipe or in a joint (Etter, 2015; Morean et al., 2017). Overall, the increasing trend of cannabis vaping in youth may be due to factors that are relatively distinct from the factors which contribute to cannabis use generally and therefore needs to be studied as a specific category of behavior.

Young adulthood, and particularly the early college years, is a critical developmental period in the initiation of drug use (Stone et al., 2012). A crucial risk factor for substance use initiation and progression in adolescence and young adulthood is peer substance use (Alexander et al., 2001; Mason et al., 2014), and peer use becomes an especially strong predictor in young adulthood (Van Ryzin et al., 2012) as friendship networks replace family networks as a source of everyday interactions. However, random sampling can mask the effects of peers and the influence of networks on behavior, through which new behaviors, such as vaping, can diffuse (Borgatti 2009; Andrews et al., 2002). Longitudinal social network methods have made more nuanced analysis of the diffusion of drug use norms and behaviors through a peer network possible, allowing for more precise identification of social relationship factors that are both predictive of and protective against drug use (Valente and Pitts, 2017). In the case of cannabis vaping, a relatively novel phenomenon, having social contact with others who engage in this behavior may greatly increase the risk that a given individual will initiate this behavior.

A recent study with adolescents found that ever use of cannabis and e-cigarettes were both associated with vaping cannabis (Morean et al., 2015); we therefore included these variables as individual predictors of cannabis use initiation in the current study. Further, sensation-seeking, a measure of impulsiveness, has been associated with the initiation of cannabis use (Haug et al., 2014) and cannabis vaping specifically (Morean et al., 2017). Thus, we also

sought to determine the role of this variable in predicting cannabis vaping initiation. Finally, the university at which this study was conducted allows students living on-campus to opt-in to living in a “substance free” dormitory in which students agree to live in an environment free of alcohol or other substance use; thus, we also wished to determine if these students were less likely to initiate this specific type of drug use.

The aims of the current study were to determine 1) the prevalence of vaping cannabis, 2) differences in social networks between individuals who initiated vaping cannabis across the first year of college and their peers, and 3) individual-level predictors and network-level of initiation of vaping cannabis. We further 4) compared the findings on predictors of cannabis vaping to predictors of initiation of any ENDS use generally in order to determine whether these behaviors share similar or different risk factors and 5) examined whether cannabis vaping was associated with an increase or decrease in frequency of cannabis use overall (i.e., to determine if participants are vaping instead of smoking). We hypothesized that risk for initiation of cannabis vaping would be highest among ever-users of either substance (ENDS and cannabis), and that overall network exposure to these substances would be predictive of vaping cannabis at any time point and of initiation of vaping cannabis during the first year of college.

2. Materials and methods

2.1 Procedure

During the fall 2016 semester at a mid-size Northeastern university, all incoming first-year students living on-campus were eligible to participate in the larger study from which these data were drawn. Students in a program for returning (not traditional age) students or not living on campus (n=14) and first-year students enrolled in a dual-degree program with another local institution (n=18) were deemed ineligible. This left a total of 1,660 students who were eligible to participate. A variety of advertising strategies were used to facilitate enrollment of a large proportion of the incoming first-year class. Matriculating students were sent post-cards and e-mails and were encouraged to participate through on-campus advertising (e.g., flyers, in-person tabling events). Prior to the first survey, students were sent a link to an online study consent form. Students 18 or older provided consent to participate. Students who were under the age of 18 provided assent, and through our online system they emailed a link to a parent or guardian who provided consent.

The first and second waves of the web-based survey were available for two weeks beginning in the sixth week of the Fall 2016 (Time 1) and Spring 2017 (T2) semesters. Surveys took an average of 45 minutes to complete and assessed a variety of substance use behaviors and related variables. Surveys also contained a series of questions to characterize participants’ ties within the complete sociocentric network of first-year students. Participants received electronic Amazon gift cards via email in the amounts of $50 and $55 for completing T1 and T2 surveys, respectively. Among the 1,660 eligible first-year students living on-campus, 1,342 (81%) completed the first survey in the Fall 2016 semester. A majority of these students (n = 1,313; 98%) also completed the second survey in the Spring 2017 semester and are included in these analyses. An analysis of the 29 participants who did not complete the T2 survey revealed that they consumed a higher number of drinks on their heaviest drinking

day (M = 6.68 vs. M = 4.53, t(1,327) = −2.57, p = .01); no other differences were found. To protect participant confidentiality, participants were assigned a unique ID number which was used to identify them from T1 to T2. Survey data were collected online using Illume (version 5.0; DatStat Inc.). Data were stored securely on a University server using secure sockets layer (SSL) encryption and firewalls to protect the data and prevent unauthorized access. All procedures were approved by the University's Institutional Review Board.

2.2 Measures

2.2.1 Demographics—Participants self-reported their age, sex, race, ethnicity, athlete status, receipt of financial aid, and first-generation status. At this University, students who are committed to living in an environment free of alcohol or other substance use can opt-into living in a "substance free" dormitory. Substance free dormitory residence was obtained from the University Registrar prior to study enrollment.

2.2.2. Cigarette smoking status—At Time 1 (T1), lifetime cigarette use was assessed by asking participants the following questions: "Have you ever smoked a cigarette?" (*Yes* or *No*). At Time 2 (T2), cigarette smoking status use was measured by the question "Since November 1st, have you smoked a cigarette?" November 1st was when the Time 1 survey closed.

2.2.3 Cannabis use—Lifetime cannabis was assessed by asking, "Have you *ever* used marijuana/cannabis/hash?" (*Yes* or *No*). If endorsed, participants were queried about their cannabis use in the past 30 days: "In the past 30 days, on how many days have you used marijuana?" (0 to 30 days). Items were adapted from the National Survey on Drug Use and Health (NSDUH; Center for Behavioral Health Statistics and Quality, 2014). Participants who endorsed past 30-day cannabis use were further queried on the method of administration. Response options included: *Smoked (joint, bowl, bong)*, *Vaped (using liquid, e.g., dab, hash oil)*, *Vaped (using ground buds)*, or *Ate (in an edible, candy, tincture, or other food)*, and participants were allowed to check any answers that applied. We did not ask participants to distinguish between types of liquid/wax THC concentrates.

2.2.4 ENDS use—We assessed lifetime and past 30-day ENDS use defined as "Electronic products, such as e-cigarettes, vape pens, hookah pens, personal vaporizers and mods, e-cigars, e-pipes, and e-hookahs. These products are battery-powered and produce vapor instead of smoke. They typically use a nicotine liquid, although the amount of nicotine can vary, and some may not contain any nicotine at all" (Hyland et al., 2017). Lifetime ENDS use was assessed by asking "Have you ever used any of the above products, including for vaping something other than nicotine?" Participants who endorsed lifetime ENDS use were then queried on which e-liquids/juices they had ever tried and were asked to select which liquid/juice they had used most often in the past 30 days. One of these response options included "*Contained marijuana concentrate (e.g., dab, hash oil)*". In analyses, any ENDS use includes all participants who endorsed lifetime ENDS use for any substance other than cannabis only; participants who reported using ENDS but then only reported using marijuana concentrate were considered cannabis vapers but excluded from the ENDS use category (N=44/329 at T1 and N=34/166 at 72.

2.2.5 Measurement of cannabis vaping—Participants were classed as cannabis vapers if they endorsed "*Vaped (using liquid; e.g., dab, hash oil)*" or *"Vaped (using ground buds)"* in the past 30 days on the cannabis use questions above or if they endorsed having ever used ENDS with marijuana concentrate (e.g., dab, hash oil) on the ENDS use questions above.

In analyses, we used an inclusive indicator of cannabis vaping to describe the prevalence of lifetime cannabis vape use at T1 and initiation at T2. Participants who endorsed vaping cannabis on any one of the three questions were considered cannabis vape users at T1 or T2. Based on participants' self-report of lifetime vaping cannabis at T1 and T2, each participant was categorized into one of four categories: 1) *abstainers* were participants who did not vape cannabis at either time point, 2) *discontinuers* were participants who vaped cannabis at T1 but not at T2, 3) *initiators* were participants who vaped cannabis at T2 but not at T1, and 4) *sustainers* were participants who vaped cannabis at both time points. We created the same variables based on participants' self-report of lifetime ENDS and cannabis use of any kind.

2.2.6 Sociocentric network—At each wave of the survey, participants were presented with a drop-down list displaying the names of all other students in the first-year class (excluding $n = 42$ and $n = 39$ students who opted out of this list at T1 and T2, respectively). Participants were instructed to select up to 10 students who were important to them in the past month (i.e., "People you socialized with, studied with, or regularly had fun with"). Within the survey programming, the student names (front end, run time variables only) were associated with IDs (back end, saved in database); using the IDs, we linked the self-report of peers with participants. Peer network vaping was derived using the four vaping cannabis categories as described above: 1) number of abstainers in the network, 2) number of discontinuers in the network, 3) number of initiators in the network, and 4) number of sustainers in the network. We also created the same network variables based on any ENDS use.

2.2.7 Sensation seeking—Participants completed the SUPPS-P Impulsive Behavior Scale (short form). The sensation seeking subscale contains four items: 1) I quite enjoy taking risks, 2) I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional, 3) I would like to fly an airplane, and 4) I would enjoy the sensation of skiing very fast down a high mountain slope. Participants responded on a four-point scale from strongly agree to strongly disagree (Lynam, 2013). Items were summed to create a total sensation seeking score ($\alpha = 0.71$).

2.3 Data analysis

Descriptive statistics provide the prevalence of vaping cannabis at T1 (lifetime use prior to Fall 2016 survey administration) and T2 (use at any time between Fall 2016 and Spring 2017). Bivariate correlations were conducted among key variables. Between-subjects t-tests were used to compare cross-sectional network characteristics among vaping cannabis initiators and those who abstained at both time points. Dependent samples t-tests were conducted to analyze the difference in past-month marijuana use at T1 and T2. Logistic regression models were employed to examine T1 and T2 predictors of initiating cannabis vaping at T2 with individual and network-level characteristics as predictors.

3. Results

3.1 Participant characteristics

Participants were 55.5% female with an average age at baseline of 18.6 years (*SD* = .51). The majority of the sample was White (55.8%), followed by Asian (23.6%), Multi-racial (10.1%), African American (6.9%), and other race (1.8%); in addition, 1.8% of the sample did not report their race. 15.4% of the sample identified as being of Hispanic ethnicity. Nearly half (47.3%) of students in this sample indicated receiving financial aid, while 16.8% reported being a first-generation student, 14.2% indicated being a student athlete, and 13.4% of students lived in a substance free dorm.

3.2 Prevalence of cannabis vaping

Table 1 displays the percent of participants who used cannabis, vaped cannabis, used ENDS, and used tobacco in their lifetime (measured at T1) and since the first survey (measured at T2). Table 1 also displays the percent of participants who are either abstainers, discontinuers, sustainers, or initiators using participants' self-report of cannabis, vaping cannabis, and ENDS use across both time points. According to the data, 1012 (77.1%) participants reported never vaping cannabis in their lifetime at both time points (abstainers), 124 (9.4%) vaped in their lifetime but not since the first survey (discontinuers), 99 (7.5%) vaped in their lifetime and since the first survey (sustainers), and 78 (5.9%) vaped since the first survey but not at T1 (initiators).

Of the 78 participants who initiated vaping cannabis between T1 and T2, 21 (26.9%) vaped liquid, 50 (64.1%) vaped ground buds, and 24 (30.8%) used an e-liquid that contained cannabis concentrate (note: these were not mutually exclusive categories). Furthermore, the majority (75.6%) of these initiators used cannabis (other than vaping, i.e., smoked or ate) at both assessments, and 24.4% used cannabis (other than vaping) at T2 but not at T1. 25 (32.1%) initiators did not use ENDS (other than to vape cannabis) at either time point, 11 (14.1%) used ENDS at T1 but not at T2, 16 (20.5%) used ENDS at both time points, and 26 (33.3%) used ENDS at T2 but not at T1.

3.3 Prevalence of cannabis vaping: Characteristics of network members (peers)

To better understand the characteristics of the social network, we first calculated network descriptive statistics. At T1, participants nominated an average of 5.49 peers (*SD* = 2.93) who completed both the T1 and T2 surveys; 89 participants did not nominate a peer who completed both surveys. In other words, 89 people at T1 either nominated 0 peers at T1 or had 0 peers complete both surveys (i.e., T1 and T2) due to dropout or change in network ties over time. At T2, participants nominated an average of 4.00 peers (*SD* = 2.70) who completed both surveys; 103 participants nominated 0 peers who completed both surveys.

At T1, on average, participants nominated 2.98 (*SD* = 2.27) peers who used cannabis, 1.10 (*SD* = 1.42) peers who vaped cannabis, and 1.56 (*SD* = 1.57) peers who used ENDS in their lifetime. Put another way, 54.3% of network members ever used cannabis, 20.0% vaped cannabis, and 28.4% used ENDS. At T2, on average, participants nominated 2.16 (*SD* = 1.98) peers who used cannabis, 0.59 (*SD*= 0.96) peers who vaped cannabis, and 0.56 (*SD* = .

94) peers who used ENDS since the first survey (T1). In other words, 54.0% of network members used cannabis, 14.8% vaped cannabis, and 14.0% used ENDS since the first survey.

3.4 Network differences in vaping cannabis initiators relative to abstainers

Independent samples t-tests were conducted to examine differences in cross-sectional network characteristics of those who initiated vaping cannabis at T2 compared to those who abstained at both time points. As shown in Table 2, relative to abstainers, those who initiated vaping cannabis at T2 had a lower number of abstaining peers in their network at T1 (i.e., those who did not vape cannabis) at either time point, a higher number of peers in their network at T1 who vaped cannabis at both time points, and higher number of peers in their network at T1 who initiated vaping cannabis themselves at T2. Furthermore, at T2, relative to abstainers, those who initiated had a lower number of peers who did not vape cannabis (i.e., a lower number of abstainers) at either time point, a higher number of peers at T2 who vaped cannabis at both time points (sustainers), a higher number of peers in their network at T2 who initiated vaping cannabis from T1 to T2, and a higher number of peers who discontinued vaping cannabis at T2. There were no differences between initiators and abstainers at T1 in the number of peers nominated at T1 who vaped cannabis at T1 but not at T2.

3.5 Individual- and network-level predictors of participant initiation of vaping cannabis

Next, we conducted a logistic regression to examine if participant and network substance use at T1 predicted vaping cannabis initiation at T2. As shown in Table 3, lifetime cannabis use, lifetime ENDS use, and number of peers at T1 who went on to initiate vaping cannabis at T2 significantly predicted participant initiating vaping cannabis. Specifically, for each network member who initiated vaping cannabis at T2 the participant had 1.6 times higher odds of initiating vaping cannabis at T2. When the predictors were at T2, cannabis use, cigarette use, ENDS use since the first survey, and the number of peers who initiated vaping cannabis at T2 were significantly associated with participant initiating vaping cannabis at T2.

3.6 Individual- and network-level predictors of participant initiation of any ENDS use

Next, using similar models as in Table 3, we examined the individual and network predictors of any ENDS initiation (i.e., including both nicotine and/or cannabis vaping) to determine whether similar or different predictive variables affected the initiation of any ENDS use. As shown in Table 4, lifetime cannabis use and cigarette use at T1 and T2 were associated with significantly increased odds of ENDS initiation at T2. At T1, the number of ENDS abstainers in the network were associated with significantly reduced odds of ENDS initiation. Network ENDS use at T2 was not predictive of participant ENDS use initiation.

3.7 Differences in cannabis use frequency across the two assessments as a function of cannabis vaping status

Finally, we conducted dependent samples t-tests to examine differences in past-month cannabis use frequency from T1 to T2 between cannabis vaping initiators, abstainers, sustainers, and discontinuers to determine whether vaping cannabis was associated with an

overall change in cannabis use frequency. Across the entire sample, the number of days of cannabis use in the past month significantly increased from T1 to T2 ($M = 2.13$, $SD = 5.14$; $M = 2.53$, $SD = 5.64$; $t(1312) = -4.19$, $p < .001$). Past-month cannabis use frequency significantly increased from T1 to T2 among cannabis vaping abstainers ($M = 0.74$, $SD = 2.67$ to $M = 1.11$, $SD = 3.42$, $t(1010) = -4.22$, $p < .001$) and among initiators ($M = 3.21$, $SD = 4.52$ to $M = 5.99$, $SD = 4.85$, $t(77) = -6.63$, $p < .001$). There was not a significant difference between T1 and T2 in the frequency of cannabis use among cannabis vaping discontinuers ($M = 4.81$, $SD = 6.56$ to $M = 4.33$, $SD = 7.06$, $t(123) = 1.02$, $p = .31$) and sustainers ($M = 12.17$, $SD = 8.82$ to $M = 12.06$, $SD = 9.90$, $t(98) = 0.21$, $p = .83$).

4. Discussion

As the use of ENDS and similar portable devices to vaporize cannabis gains popularity among young people, it is important to identify which subpopulations of young adults are most at risk of initiating this behavior. As young adults in college are strongly influenced by their social networks, we examined how the initiation of vaping cannabis was affected by peers' use in a cohort of students in their first year of college. We examined both individual-level predictors (ENDS use and cannabis use at the beginning of the year) and exposure to cannabis-using, any ENDS-using, and cannabis vaping peers across the year as predictors for initiation of this behavior and compared these to risk factors for initiating ENDS use generally.

Lifetime cannabis use at the beginning of the year was strongly predictive of initiation of vaping cannabis during the first year of college. Lifetime ENDS use and ENDS use from T1 to T2 was also predictive of cannabis vaping initiation, as was cigarette use between T1 and T2. Overall, these data indicate that students who have previous experience with using cannabis in other forms and experience with ENDS are more likely to engage in this novel form of use. This is consistent with data from an adolescent sample in which lifetime use of any cannabis and ENDS use was predictive of vaping cannabis (Morean et al., 2015). In terms of social network predictors, we tracked the evolution of this behavior in each individual's social network to determine how the status of network members with regard to initiation of vaping cannabis changed across the year. We found that the presence of fellow initiators, but not sustainers, in participants' close networks was predictive of initiation of cannabis vaping. Importantly, neither the number of peers using cannabis nor the number of peers using any ENDS at each time point was predictive of cannabis vaping initiation. These results suggest that mere exposure to ENDS use or cannabis use by peers is not enough to prompt cannabis vaping; peers must be engaging in cannabis vaping specifically to pose a risk to others in their network, and this risk is especially salient when others in the network are first learning this behavior (i.e., initiating) themselves.

We also examined how this pattern of results was similar to or different from initiation of any ENDS use in order to determine if the same risk profile was associated with initiation of vaping cannabis and initiation of using an ENDS device for any substance (including both nicotine and cannabis). We found again that using cannabis at T1 was predictive of initiation of any ENDS use, as it was for cannabis vaping, and cigarette use was a stronger predictor for ENDS initiation than for cannabis vaping initiation at both time points. In contrast to the

findings for cannabis vaping, we did not find that the behavior of other ENDS users in the network was associated with increased odds of initiating any ENDS use, nor were the presence of cannabis users at either time point. For cannabis vaping initiation, the nomination of greater numbers of cannabis vaping-initiating peers at T2 was associated with initiation of cannabis vaping. These results suggest that the initiation of vaping cannabis specifically may be more sensitive to peer influence than the initiation of any ENDS use.

Given that previous cannabis use was predictive of initiation of vaping cannabis, we were also curious about the extent to which cannabis vaping students were replacing some of their cannabis use with vaping, and therefore reducing or maintaining their overall frequency of cannabis use, or whether they were adding cannabis vaping to their usual cannabis use and therefore increasing their overall frequency of use. We found that cannabis vaping initiators increased their frequency of cannabis use over time, suggesting that vaping was not a replacement behavior and may therefore increase the overall risk of dependence in these youths. Those individuals who vaped cannabis at both time points did not show an increase in overall cannabis frequency across the year; however, their overall frequency was threefold higher than that of the initiator group (M=12.1 vs M=3.2 cannabis using days out of the last 30 days at T1).

Strengths of our sample include the longitudinal design and ability to track dynamic changes in the self-reported behavior of network members of over time. The study is innovative in its use of a complete (sociocentric) network approach, which allowed us to assess not only participants' perceptions of their peers' drug use but also those same peers' self -reported use. This is a strength over the majority of social network studies using an egocentric approach which relies on participants' perceptions of nominated peers' behavior. Further, this sample is the first to our knowledge to track the initiation of cannabis vaping in young adults. Limitations of the study include that we found relatively high rates of cannabis use relative to nationally reported rates (20% past-month use rate in full-time college students aged 18–22 year olds compared to 34% in our sample; SAMHSA, 2017). Thus, our population may represent a particularly high-risk population given that any cannabis use appears to be strongly predictive of cannabis vaping. Further, in the state in which these data were collected, cannabis use is not currently legal for recreational use. This distinction is likely crucial for determining how these novel products are obtained and perceived, which will differentially impact initiation rates across states. We also included only first-year students as participants and network members, which precluded examining potential relationships with older students. Another limitation is the decrease in the number of peers nominated from T1 to T2. This is likely due to assessment reactivity (i.e., participants nominated fewer peers at T2 to reduce the length of the survey) and may have resulted in less comprehensive information about peers at T2. We also classified networks based on number of peers in each category, rather than as a proportion of peers, in order to include all four categories in the model while avoiding multicollinearity issues; however, this does not allow us to control for differences in the total number of peers nominated across participants. Furthermore, for participants (who were also networked peers) to be categorized based on self-reported longitudinal cannabis vaping use, they had to complete both surveys. It is unknown whether eligible students who did not enroll in the study (n = 318) or who were lost to follow up (n = 29) differed significantly on important characteristics from students

who completed (or were nominated) at both time points. Another limitation of the study is that we were not able to determine which form 'liquid' THC vaping took: participants could have been using wax, butane hash oil, or e-liquid concentrates that contained THC. Finally, although the longitudinal design of this study allowed us to predict the initiation of vaping cannabis and document changes in frequency of cannabis use prior to and contemporaneous with cannabis vaping initiation, we were not able to determine the frequency of subsequent use. More follow-up data is needed to determine how initiation of cannabis vaping affects the overall frequency of cannabis use over time.

Overall, these data point to a risk profile for initiation of cannabis vaping of youth who have already used cannabis in other forms, who may have experience with using ENDS, and who then make friends with other youth who go on to initiate cannabis vaping. Given that cannabis vaping is a non-standard form of cannabis ingestion, individuals may be experimenting and learning this behavior as a group. As the landscape of cannabis and tobacco product regulation changes, the potential risks from novel methods of use should inform policymakers to best protect the future health of young people.

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Highlights

- We analyzed a longitudinal social network sample of first-year college students.
- Lifetime cannabis use and electronic nicotine delivery systems (ENDS) use were risk factors for beginning cannabis vaping.
- Close peers who initiated cannabis vaping also increased risk for initiation.

Table 1

Number and percent of participants who used cannabis, vaped cannabis, used ENDS, and used tobacco in their lifetime (T1) and since the first survey (T2). Number and percent of participants who were abstainers, discontinuers, sustainers, or initiators of cannabis use, vaping cannabis, and ENDS use.

	Number (Percent) reported		
	T1	**T2**	**Across both assessments**
Cannabis use	627 (47.8)	597 (45.5)	
Abstainers			579 (44.1)
Discontinuers			136 (10.4)
Sustainers			491 (37.4)
Initiators			106 (8.1)
Vape cannabis	223 (17.0)	177 (13.5)	
Abstainers			1012 (77.1)
Discontinuers			124 (9.5)
Sustainers			99 (7.5)
Initiators			78 (5.9)
ENDS use[1]	285 (21.7)	132 (10.1)	
Abstainers			979 (74.6)
Discontinuers			201 (15.3)
Sustainers			84 (6.4)
Initiators			48 (3.7)
Tobacco use	291 (22.2)	195 (14.9)	

Note. Based on participants' self-report of lifetime use of cannabis, vaping cannabis, and ENDS, respectively, at T1 and T2, each participant was categorized into one of four categories: 1) *abstainers* were participants who did not use that substance at either time point, 2) *discontinuers* were participants who used that substance—at T1 but not at T2, 3) *initiators* were participants who used that substance at T2 but not at T1, and 4) *sustainers* were participants who used that substance at both time points.

[1] Any ENDS use other than vaping cannabis.

Table 2

Differences between participants who initiated vaping cannabis (N = 78) and those who abstained from vaping cannabis at both time points (N = 1012) on the number of nominated peers in the network who were abstainers, sustainers, initiators, and discontinuers at Time 1 (T1) and Time 2 (T2).

	Participants who initiated vaping cannabis	**Participants who abstained from vaping cannabis**		
	M (SD)	***M (SD)***	***t***	***p***
Nominated at Time 1 (T1)				
Number of peers who abstained from vaping cannabis	3.68 (2.30)	4.76 (2.43)	3.71	0.0002
Number of peers who sustained vaping cannabis	0.72 (0.92)	0.36 (0.72)	−3.31	0.001
Number of peers who initiated vaping cannabis	0.72 (0.91)	0.28 (0.60)	−4.13	0.0001
Number of peers who discontinued vaping cannabis	0.61 (0.80)	0.48 (0.78)	−1.40	0.16
Nominated at Time 2 (T2)				
Number of peers who abstained from vaping cannabis	2.70 (2.13)	3.55 (2.31)	3.00	0.003
Number of peers who sustained vaping cannabis	0.54 (0.83)	0.21 (0.54)	−3.22	0.002
Number of peers who initiated vaping cannabis	0.68 (0.94)	0.21 (0.49)	−4.21	0.0001
Number of peers who discontinued vaping cannabis	0.55 (0.81)	0.34 (0.66)	−2.11	0.038

Table 3

Logistic regression with T1 and T2 variables predicting vaping cannabis initiation. This analysis compared those who initiated vaping cannabis (N = 78) and those who abstained from vaping cannabis at both time points (N = 1012).

	T1 predictors (lifetime)			T2 predictors (since T1)		
		95% C.I. for Exp(B)			95% C.I. for Exp(B)	
Predictor	**Exp(B)**	**Lower**	**Upper**	**Exp(B)**	**Lower**	**Upper**
Sex	0.93	0.55	1.57	1.20	0.69	2.09
Substance free dorm	0.41	0.09	1.79	0.28	0.07	1.21
Sensation seeking	1.01	0.92	1.12	0.99	0.90	1.10
Cigarette use	1.57	0.87	2.83	2.23*	1.11	4.51
Cannabis use	3.02***	1.63	5.61			
ENDS use	2.13*	1.20	3.79	5.18***	2.54	10.57
Number of peers who used cannabis	1.08	0.87	1.33	1.17	0.89	1.54
Number of peers who used ENDS	1.01	0.78	1.31	0.99	0.73	1.35
Number of peers who abstained from vaping cannabis	0.87	0.75	1.00	0.87	0.73	1.04
Number of peers who discontinued vaping cannabis	0.84	0.58	1.23	0.98	0.63	1.53
Number of peers who sustained vaping cannabis	1.19	0.81	1.74	1.34	0.82	2.20
Number of peers who initiated vaping cannabis	1.69**	1.20	2.37	1.69*	1.06	2.70

[a]Cannabis use was not a predictor at T2 because all 78 participants who initiated vaping cannabis at T2 reported T2 cannabis use.

Table 4

Logistic regression with T1 and T2 variables predicting ENDS initiation. This analysis compared those who initiated ENDS use (N = 48) those who did not use ENDS at either time point (N = 979).

	T1 predictors (lifetime)			T2 predictors (since T1)		
		95% C.I. for Exp(B)			95% C.I. for Exp(B)	
Predictor	**Exp(B)**	**Lower**	**Upper**	**Exp(B)**	**Lower**	**Upper**
Sex	0.75	0.39	1.42	0.82	0.41	1.64
Substance free dorm	1.06	0.23	4.91	0.64	0.14	2.96
Sensation seeking	1.04	0.92	1.17	1.06	0.93	1.20
Cigarette use	2.42*	1.21	4.84	6.42***	2.96	13.94
Cannabis use	6.11***	2.33	15.99	3.73**	1.50	9.27
Number of peers who used cannabis	1.16	0.87	1.56	1.11	0.78	1.59
Number of peers who abstained from ENDS use	0.74**	0.60	0.92	0.82	0.65	1.04
Number of peers who discontinued ENDS use	0.88	0.58	1.33	0.58	0.33	1.01
Number of peers who sustained ENDS use	1.43	0.93	2.20	1.15	0.67	1.98
Number of peers who initiated ENDS use	0.82	0.41	1.67	1.42	0.60	3.38

Note: ENDS use does not include the participants who only used ENDS with marijuana concentrate (T1 = 44 and T2 = 34). At T2, the number of people who discontinued ENDS use trended on significance (p = .053).