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E-cigarette Use, Poly-tobacco Use, and Longitudinal Changes in Tobacco and Substance Use Disorder Symptoms among U.S. Adolescents

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Abstract

Purpose: The objective of this study is to examine the combinations of e-cigarette use, cigarette use, and other tobacco use over-time and the relationship these longitudinal use patterns have with symptoms of tobacco use disorder (TUD) and substance use disorders (SUDs) among a sample of adolescents.

Methods: Data from U.S. adolescents (ages 12 to 17) who were surveyed for the Population Assessment of Tobacco and Health (PATH) Study at baseline, first follow-up, and second follow-up (2013–14, 2014–15, and 2015–16; n=7,595) was used to analyze symptoms of TUD and SUDs based on longitudinal combinations of tobacco/nicotine use.

Results: The most common combination of tobacco/nicotine use across the three waves was “no use of any tobacco/nicotine products” at baseline and first follow-up to “e-cigarette use only” at the second follow-up. Multivariable analyses found that past 30-day cigarette use and other tobacco use at the most recent follow-up was associated with an increase in both current TUD and

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Declaration of Conflicts or Interests

The authors have no conflict of interest to report.

SUD symptoms, while past 30-day e-cigarette use at the most recent follow-up was modestly associated with an increase in current SUD symptoms.

Conclusions: Individuals who transitioned to e-cigarette use were at relatively low risk for increased TUD and SUD symptoms. However, individuals who transitioned or continually used cigarettes were typically at greater risk for indicating more TUD and SUD symptoms. Given the low risk of e-cigarette only users to indicate TUD and SUD symptoms, prevention efforts need to be made to target these youth before they transition to cigarettes and other types of tobacco use.

Keywords

E-cigarettes; Tobacco Use; Substance Use Disorders

Introduction

Tobacco use remains a leading cause of morbidity and mortality in the U.S.; nearly all tobacco users initiate use during adolescence and early adulthood[1,2]. Consequently, we have an urgent need to understand patterns of tobacco use among youth and how these patterns are associated with later risk of tobacco use disorder (TUD) and other substance use disorders (SUDs). Nicotine exposure during adolescence can have negative effects on youths' developing brain and increase risk of addiction[3]. Despite reductions in cigarette use among adolescents in the last decade, tobacco use has remained relatively stable; this is, in part, due to increased consumption of e-products (e.g., JUULs), including e-cigarettes[4,5]. E-cigarette use among adolescents in the U.S. has continued to climb and is more commonly used than cigarettes within this population since 2014[6].

Our understanding of relationships between e-cigarettes and their impact on later tobacco use, TUDs and SUDs is limited[7]. Researchers suggest that e-cigarettes and other types of e-products are associated with combustible cigarette use[8]. Youth using e-cigarettes generally perceive them as safer and more socially acceptable than combustible cigarettes, but the potential exposure to nicotine may facilitate a transition to cigarette or other tobacco use[8].

Poly-tobacco use, the concurrent use of multiple tobacco products, is also increasingly common among youth in the U.S.[7]. Poly-tobacco users are likely to be users of e-products including e-cigarettes[9]. The recent rise in e-products has been accompanied by an increase in poly-tobacco use, with 41.7% of adolescents currently using tobacco engaging in poly-tobacco use[4]. This is of particular concern because nicotine is a highly addictive drug[10–12], and when youth engage in dual use (i.e., e-cigarette and cigarette use) they can potentially be exposed to higher levels of nicotine than with simply using only one tobacco product[12]. Certain nicotine/tobacco use patterns may be associated with progression to more harmful and diverse poly-tobacco use that increase risk of TUDs and SUDs[13]. Further, “vaping” with e-cigarettes/e-products is associated with vaping non-nicotine substances, including marijuana oil[14], and may increase the risk of engaging in other types of substances or developing SUDs.

Unlike our knowledge of cigarette use among youth and its relationship to other social and health behaviors, more needs to be known about the short- and long-term consequences of youth e-cigarette/e-product use in relation to the dual use of e-cigarettes with cigarettes and other forms of tobacco use[15]. Several studies have begun to examine health consequences of e-cigarette use and dual use[16–19]. In particular, Leventhal et al.[16] found an ordered pattern whereby externalizing comorbidity (i.e., alcohol, cannabis and other drug misuse) was lowest among nonusers, moderate in single product users and highest in dual users in a cross-sectional regional sample of 9th graders in Los Angeles. Moreover, a study using the Population Assessment of Tobacco and Health (PATH) Study[18] found that among youth, any lifetime e-cigarette and cigarette use at baseline predicted subsequent substance use in the following year. Other research using PATH data using adolescent samples have examined how e-cigarettes and other types of nicotine/tobacco use predict later cigarette use[19] and bidirectional associations between tobacco use and other substance use[18], but have not examined the combinations of e-cigarette use, cigarette use, and other tobacco use over time and how these may be associated with later symptoms of TUD and SUD.

While there has been an increased effort to address the consequences of e-cigarette use, the National Academies of Science, Engineering, and Medicine[15] noted that more research was needed regarding assessments and outcomes related to dependence symptoms for both nicotine and other substances in order to better understand risks of e-cigarette use. Accordingly, this study addresses a current gap in the literature by prospectively determining (1) the combinations of e-cigarette use, cigarette use, and other tobacco use over time and (2) the relationship these longitudinal use patterns have with symptoms of TUD and SUD.

Methods

The present study used the PATH Study, a nationally representative data set of youth (ages 12 to 17) who were assessed at three separate time points: baseline/Wave 1 (September/2013–December/2014), first follow-up/Wave 2 (October/2014–October/2015), and second follow-up/Wave 3 (October/2015–October/2016)[20–21]. The PATH Study used a four-stage stratified area probability sample design to ensure a nationally representative sample. The PATH Study interview for youth used audio computer-assisted self-interviewing (ACASI) and on-screen displays and flashcards to aid respondents. Response rates at Wave 1, 2 and 3 were 78.4%, 83.2%, and 83.3% respectively. The retention rate within the youth sample was 88.4%; it should be noted that youth who dropped out at Wave 2 were more likely to engage in nicotine/tobacco use and to have a higher number of TUD and SUD symptoms at Wave 1 when compared to the sample who continued to participate in the study. Additionally, the average length between baseline and first follow-up among the adolescent sample was 12.8 months (Mean=12.8, SD=2.2, range=2.8–26.5); the average length between first follow-up and second follow-up was 12.7 months (Mean=12.7, SD=1.4, range=8.8–23.0).

Sample analyzed from PATH Study

The current study utilized data from the PATH Study, specifically, youth who completed Waves 1, 2, and 3 using the *youth questionnaire*. Restricting the sample to these parameters provided us with an analytic sample of 7,795 youth who participated across the three waves

of the youth study. Table 1 provides relevant sample characteristics regarding demographics and the key variables used in the analyses.

Past 30-day tobacco use

Past 30-day cigarette, e-cigarette, and other tobacco use were measured with a set of items that asked respondents the following: “In the past 30 days, on how many days did you smoke cigarettes?” and “In the past 30 days, on how many days did you use an e-cigarette?” Other tobacco use was captured with the same set of questions that asked about past 30-day use with the following items: “traditional-cigar”, “cigarillo”, “filtered-cigar”, “pipe”/“hookah”, “smokeless-tobacco”, “snus-pouches”/, “dissolvable-tobacco products”, “bidis”, “kretek”. The response options ranged between 0 to 30 days. The nicotine/tobacco items were recoded to dichotomous measures to reflect past 30-day use. Other tobacco use combined the ten items listed above. An additional set of control variables were constructed to capture lifetime use, but not in the past-year, at Wave 1 for cigarette use, e-cigarette use, and other tobacco use. Finally, it should be noted that past 30-day tobacco use was used instead of past-year use in order to minimize recall bias (results based on past-year use were similar and can be provided upon request).

For descriptive purposes, we constructed the 64 different possible combinations of nicotine/tobacco use based on ‘no past 30-day nicotine/tobacco use’, ‘past 30-day cigarette use’, ‘past 30-day e-cigarette use’, and ‘past 30-day other tobacco use’ at Wave 1 and 2. Additionally, we constructed the 512 different possible combinations of tobacco use based on the same four categories at Wave 1, 2, and 3. In order to appropriately report on mean symptom counts and ease of presentation, we provide ten of the most common tobacco use combinations. It should be highlighted that limiting the presentation to the ten most common nicotine/tobacco use combinations (we only restrict the sample in Table 3) still represents 67.7% of nicotine/tobacco users at Wave 1 and 2, and 55.1% of nicotine/tobacco users at Wave 1, 2 and 3.

TUD symptoms (past-year)

TUD symptoms were assessed with six separate items at Wave 1, 2, and 3 among respondents who indicated any past-year tobacco use. The TUD items were based on a smaller subset of questions from the Wisconsin Inventory of Smoking Dependence Motives (WISDM-68)[22] and included the following: (1) “I frequently crave tobacco”, (2) “My tobacco use is out of control”, (3) “Using tobacco really helps me feel better if I’ve been feeling down”, (4) “Using tobacco helps me think better”, (5) “I would feel alone without my tobacco”, and (6) “I usually want to use tobacco right after I wake up”. The five response options ranged on a scale of 1 (i.e., “not at all true of me”) to 5 (i.e., “extremely true of me”). Items were recoded to dichotomous measures to reflect past-year symptoms (i.e., “not true of me at all” versus any positive endorsement of responses 2 through 5). The sum of the six items was used in the current analysis. Refer to Table 2 for additional details.

SUD symptoms (past-year)

Past-year symptoms of SUD were assessed with six separate items at both Wave 1 and Wave 2. The SUD items were based on a modified[23] version of the Global Appraisal of

Individual Needs—Short Screener (GAIN-SS)[24] and included the following items for potential symptoms of SUDs: (1) “Last time that you spent a lot of time either getting alcohol or other drugs”; (2) “Last time that you kept using alcohol or other drugs even though it was causing social problems, leading to fights, or getting you into trouble with other people”; (3) “Last time that your use of alcohol or other drugs caused you to reduce your involvement in activities at work, school, home or social events”; (4) “Last time that you spent a lot of time using or recovering from alcohol or other drugs”; (5) “Last time that you had withdrawal problems”; and (6) “Last time that you used alcohol or other drugs to stop being sick or avoid withdrawal problems”. Response items included “past month”, “2 to 12 months ago”, “over a year ago”, and “never”. Items were recoded to dichotomous measures to reflect symptoms in the past year. A sum of the six items was used in the current analysis. Refer to Table 2 for the descriptive statistics and reliability estimates for each of these items across the three waves of the study. Refer to Table 2 for additional details.

Control variables

To account for additional confounding factors in the analyses, we also included several relevant demographic variables (e.g., sex) and measures of lifetime substance use (e.g., lifetime alcohol use)[18,25–33]. Refer to Table 1 for more details on all of the control variables.

Analysis

First, we assess some of the basic descriptive characteristics of the sample with a specific focus on past 30-day nicotine/tobacco use, TUDs, and SUDs across the three waves of the survey. Second, the ten most common nicotine/tobacco use combinations between Waves 1 and 2, and between Waves 1, 2, and 3 were assessed. Third, multiple linear regression was used to assess the association between different types of past 30-day nicotine/tobacco use and TUDs/SUDs when controlling for key covariates (please refer to the footnotes in Tables 4 and 5 for these covariates). The analyses specifically focuses on how different types of past 30-day nicotine/tobacco use at each Wave are associated with both the current number of TUD/SUD symptoms and the change in TUD/SUD symptoms between Waves 1 and 2, and Waves 1 and 3.

It should be noted that all analyses used longitudinal weights (i.e., Wave 3 youth all-waves longitudinal weight) and designated variables (i.e., primary sampling unit [PSU] and stratum indicator for variance estimation) to account for the complex sampling design[21]. Stata 15.0 was used for all the descriptive analyses presented. The multiple linear regression models were estimated in Mplus (version 8) in order to account for missing values across the items used in the analyses (analyses used Full Information Maximum Likelihood Estimation). Finally, it should be noted that negative binomial regression was also used with respect to the models assessing the number of TUD and SUD symptoms at Wave 2 and at Wave 3 (this was done given that the distribution is skewed to the right [i.e., the majority of respondents had 0 TUD and SUD symptoms]); however, the interpretation of results were relatively similar across these analyses. Accordingly, we report on the results from the linear regression models for ease of interpretation given that we are interested in average symptom counts.

Results

Table 1 provides the descriptive results for the longitudinal sample of youth who completed three waves of the youth interview questionnaire. Accordingly, all types of nicotine/tobacco use increased across the three waves. For instance, 1.6% of youth indicated using e-cigarettes during the past 30-days at Wave 1, this increased to 5.7% at Wave 3. Additionally, we also see both past-year TUD and SUD symptoms increase across the three waves.

Table 2 shows the individual symptoms for both past-year TUD and SUD. With respect to TUD symptoms, the most commonly endorsed item across the three waves was ‘tobacco helps me feel better if I’ve been feeling down’. Roughly 1 out of 4 past 30-day nicotine/tobacco users endorsed this item at Wave 2 and 3. Additionally, the most commonly endorsed SUD item across the three waves was ‘spent a lot of time either getting alcohol or other drugs’.

Table 3 presents the descriptive results for the sample of the ten most common past 30-day nicotine/tobacco use combinations during Waves 1 and 2 (w1 and w2), and Waves 1, 2, and 3 (w1, w2, and w3) of the study. Assessing Wave 1 and 2, the majority of the sample indicated no nicotine/tobacco use at both waves of the study; followed by (w1) no nicotine/tobacco use to (w2) other tobacco use only (18.2% of users); (w1) no use to (w2) e-cigarette use only (16.1% of users); and (w1) no use to (w2) cigarette use only (9.93% of users). When assessing Wave 1, 2, and 3, the results change slightly with respect to 30-day users. Namely, the most common nicotine/tobacco use pattern across the three waves was (w1) no nicotine/tobacco use (w2) to no nicotine/tobacco use (w3) to e-cigarette use only (13.2% of users); this was followed by (w1) no nicotine/tobacco use (w2) to no nicotine/tobacco use (w3) to other tobacco use only (11.8% of users).

Table 3 also descriptively shows that the highest TUD and SUD symptom counts align with patterns that include cigarette use. For instance, respondents who used cigarettes only during the past 30-days at Wave 1 and Wave 2 endorsed roughly 3 TUD symptoms at Wave 2. Moreover, respondents with no history of past 30-day nicotine/tobacco use at Wave 1 and Wave 2, but indicated past 30-day cigarette use only at Wave 3 indicated roughly 1 TUD symptom at Wave 3.

Multiple linear regression was used to indicate which type of past 30-day nicotine/tobacco use across the three waves of the study was associated with current TUD/SUD symptoms. Table 4 and 5 show the results from the multiple regression analyses including unstandardized regression coefficients adjusting for sociodemographic, lifetime substance use, and nicotine/tobacco use history of non-users at Wave 1 among the full sample and among those who reported any past 30-day nicotine/tobacco use at any wave of the study. With respect to current TUD symptoms, the results indicate that current 30-day cigarette use and 30-day other tobacco use are associated with a higher number of current TUD symptoms (no association with current TUD symptoms was found with past 30-day e-cigarette use across the study period). For instance, among 30-day users, cigarette use at Wave 3 was associated with at least 1 TUD symptom at Wave 3 ($b=1.139$, $p<.001$). These results are further confirmed/corroborated when we look at the results for TUD difference

scores between Wave 1 and 2, and Wave 1 and 3. For instance, past 30-day cigarette use at Wave 3 was associated with an increase of roughly 1 TUD symptom between Wave 1 and Wave 3 among the sample of 30-day users ($b=1.105$, $p<.001$).

Table 4 and 5 also show how different types of past 30-day nicotine/tobacco use across the study period was associated with current SUD symptoms. The results indicate that current 30-day cigarette use, e-cigarette use (only at Wave 3), and other tobacco use are associated with a higher number of current SUD symptoms. For example, among past 30-day users, other tobacco use at Wave 3 was associated with roughly half of an SUD symptom at Wave 3 ($b=.457$, $p<.01$). Again, these results are further reinforced when we look at the results for SUD difference scores between Wave 1 and 2, and Wave 1 and 3.

Discussion

This study shows several important findings as it relates to changes in tobacco and e-cigarette use and how specific forms of nicotine/tobacco use increases the risk of developing both TUD and SUD symptoms among adolescents. It was found that the most common combination of past 30-day use between Wave 1 and 2 was from no use at Wave 1 to other tobacco use at Wave 2. However, between Waves 1 and 3, the most common pattern switched from no use at Wave 1 and 2 to e-cigarette use at Wave 3 (roughly 1 out of 10 past 30-day users across the study period). These patterns highlight the fact that while e-cigarettes are increasing in popularity among U.S. adolescents[34–35], it appears that other forms of tobacco consumption still greatly contribute to nicotine exposure and the subsequent symptoms of TUDs among youth. In particular, other tobacco use had a substantial impact on both TUD and SUD symptoms (more so than e-cigarette use).

It is notable that the most common pattern of past 30-day use across the three waves was youth who did not use nicotine or tobacco at Wave 1 and 2, but transitioned to the use of e-cigarettes at Wave 3. This is consistent with other research that has found that the transition from non-user to e-products/e-cigarettes is among the most common among adolescents[13]. One out of ten past 30-day users fell into this pattern and this group reported a slightly higher number of SUD symptoms when compared to their peers who did not use any nicotine or tobacco over the study period. Interestingly, this group of e-cigarette users did not have an increase in the number of TUD symptoms reported between Wave 1 and 2, or between Wave 1 and 3. While TUD and SUD symptoms remained relatively low among e-cigarette only users, this is of particular public health concern given that few youth transition from e-product use (e.g, e-cigarette use) to non-use[13] and this can have profound implications on longer-term health risks.

As expected, U.S. adolescents who used only cigarettes or multiple nicotine/tobacco products in combination with cigarettes had the highest number of both TUD and SUD symptoms. These findings vertically extend results from previous cross-sectional studies that found dual users were at significantly greater risk for other substance use behaviors, other problem behaviors, and psychiatric symptoms than single product users[16,36–38]. Furthermore, the present study found the biggest increase in TUD symptoms were among adolescents who did not use any tobacco products during the past 30-days at Wave 1, but

then indicated past 30-day cigarette use at either Wave 2 or Wave 3. SUDs and TUDs continue to be a major public health problem in the U.S. that have significant long-term impacts on the health of adolescents[39]. Consequently, understanding nicotine and tobacco use patterns that exacerbate risk of TUDs/SUDs is critical to improving the health of youth. Indeed, the findings of the present study identify several high-risk nicotine/tobacco use patterns that are in need of further assessment and services, especially those using multiple nicotine/tobacco products.

Finally, several limitations should be noted. First, the current study only examines the short-term impact of tobacco use and its impact on developing symptoms over a three-year span. Second, the use of self-report measures of substance use in the PATH Study is a clear limitation, but its use permits further consideration of a large longitudinal national sample of adolescents to track many types of tobacco use behaviors at a critical stage of human development. Third, the study collapses ten types of tobacco use (i.e., 'other tobacco use') to simplify the presentation of results, precluding a deeper understanding of what combination of specific other tobacco products consumption has the strongest association with both TUD and SUD symptoms. Forth, this study uses a sample of adolescents who were followed between 2013 and 2016 and does not capture recent changes in e-cigarette/e-product use over the past three years [40]. Finally, the temporal ordering of past 30-day tobacco/e-product use and past-year occurrences of TUD/SUD symptoms is a potential limitation of the study and may have been more accurate with a measures assessing current TUD/SUD symptoms (note that past 30-day use was chosen to minimize recall bias). However, it should be noted that the results were consistent when we assessed the association between past-year tobacco/e-product use and past-year TUD/SUD symptoms (results can be provided upon request). Despite each of these limitations, it must be highlighted that no other large-scale epidemiological studies of adolescents have TUD or SUD symptoms in order to see the impact of e-cigarette/e-product use on certain types of SUDs.

In summary, this study uses national longitudinal data of adolescents in the U.S. and brings needed epidemiological data to understand the patterns of e-cigarette, cigarette, and other tobacco use and how these patterns are associated with TUD and SUD symptoms over time. This study fills an important gap by contributing new knowledge and providing implications for future policy and research. While e-cigarette use has increased among U.S. adolescents in recent years, the present study shows that other forms of tobacco consumption contribute greatly to subsequent TUD and SUD symptoms, especially those using multiple nicotine/tobacco products. Accordingly, the findings indicate the importance of targeting prevention efforts towards youth before they transition to cigarette use. All forms of tobacco use need to be accounted for when studying the impact of e-cigarette use on adolescent health. As already noted, it will be important to establish how TUD varies across products and frequency of their use, using more fine grained behavioral measurements of use occasions, and product use within occasions. In the future, researchers can build on these findings and focus on longer-term consequences, use trajectories among sub-groups, and health consequences of adolescent e-cigarette use while accounting for the important role of other substance use.

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Article Abbreviations

ACASI	audio computer-assisted self-interviewing
e-cigarettes	electronic cigarettes
e-products	electronic vaporizing products
GAIN-SS	Global Appraisal of Individual Needs Short Screener
PATH Study	Population Assessment of Tobacco and Health Study
SUD	substance use disorder
TUD	tobacco use disorder
WISDM-68	Wisconsin Inventory of Smoking Dependence Motives-68

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Implications and Contribution:

While e-cigarettes continue to increase in popularity, other forms of tobacco consumption still contribute to nicotine exposure and subsequent symptoms of tobacco use disorder among youth. Accordingly, all forms of tobacco use still need to be accounted for when studying the impact of e-cigarette use on adolescent health.

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Table 1.

Demographic, substance use, and past 30 day nicotine/tobacco use study sample characteristics from Population Assessment of Tobacco and Health (PATH) Study (n = 7,595)

	n Unweighted	%/mean (SE) Weighted
Sex^a		
Male	3910	51.4% (.006)
Female	3665	48.6% (.006)
Race^b		
White	4868	69.8% (.013)
Black	1159	15.7% (.010)
Other	1151	14.5% (.007)
Hispanic ethnicity		
Non-Hispanic	5225	77.2% (.014)
Hispanic	2201	22.8% (.014)
Age (Wave 1)^c		
12 to 14 years of age	5733	75.1% (.004)
15 to 17 years of age	1862	24.9% (.004)
Household income^d		
\$24,999 or lower	1565	18.6% (.009)
\$25,000 to \$49,999	1835	23.0% (.006)
\$50,000 to \$99,000	2010	27.7% (.007)
\$100,000 or higher	1983	30.7% (.013)
U.S. region^e		
Northeast	1061	16.6% (.009)
Midwest	1698	21.8% (.013)
South	2829	37.6% (.015)
West	2007	24.0% (.013)
TUD/other SUD symptom counts (past-year)		
TUD (Wave 1)	100	0.048 (0.005)
TUD (Wave 2)	174	0.092 (0.008)
TUD (Wave 3)	204	0.116 (0.010)
SUD (Wave 1)	448	0.117 (0.007)
SUD (Wave 2)	651	0.161 (0.009)
SUD (Wave 3)	683	0.165 (0.009)
Past 30 day nicotine/tobacco use		
Past 30 day cigarette use (Wave 1)	158	2.1% (.002)
Past 30 day e-cigarette use (Wave 1)	121	1.6% (.001)
Past 30 day other tobacco use (Wave 1)	145	1.9% (.002)

	n Unweighted	%/mean (SE) Weighted
Past 30 day cigarette use (Wave 2)	255	3.5% (.003)
Past 30 day e-cigarette use (Wave 2)	226	3.2% (.003)
Past 30 day other tobacco use (Wave 2)	301	4.0% (.002)
Past 30 day cigarette use (Wave 3)	336	4.6% (.003)
Past 30 day e-cigarette use (Wave 3)	401	5.7% (.004)
Past 30 day other tobacco use (Wave 3)	440	5.9% (.004)
Substance use^f		
Lifetime alcohol use (Wave 1 – 3) ^f	2151	29.1% (.008)
Lifetime marijuana use (Wave 1 – 3) ^f	256	3.4% (.002)
Lifetime nonmedical prescription drug use (Wave 1 – 3) ^g	555	7.4% (.003)
Lifetime illicit drug use (Wave 1 – 3) ^h	68	1.0% (.001)

Notes: n = unweighted sample size; Percentages and means incorporate longitudinal survey weights for Wave 3; SE = standard error; TUD = tobacco use disorder; SUD = substance use disorder.

^aSex of respondent was a derived variable (i.e., PATH constructed the variable) from the interview and included either 'Male' or 'Female'.

^bRace of respondent was a derived variable from the interview and included either 'White alone', 'Black alone', and 'Other'.

^cAge of respondent was a derived variable from the interview and included either '12 to 14 years old' and '15 to 17 years old'.

^dHousehold income was a derived variable from the interview and include five categories: 'less than \$10,000', '\$10,000 to \$24,999', '\$25,000 to \$49,999', '\$50,000 to \$99,999', and '\$100,000 or more'. The maximum income indicated in either Wave 2 or Wave 3 was used for the analysis. A derived variable for household income is not included at Wave 1.

^eRegion was a derived variable from the interview.

^fAll lifetime use of substances were asked with the following manner: For instance, "Have you ever used...[alcohol at all, including sips of someone's drink or your own drink], [marijuana, hash, THC, grass, pot or weed]. Note that lifetime use was based on any indication of use between Wave 1 and Wave 3.

^gNonmedical prescription drug use included measures for 'Ritalin or Adderall' and 'painkillers, sedatives or tranquilizers'.

^hIllicit drug use included measures for 'cocaine or crack', 'methamphetamine or speed', and 'any other drugs like heroin, inhalants, solvents or hallucinogens'.

Table 2:

Frequency of past-year tobacco use disorder symptoms (TUD) and substance use disorder symptoms (SUD) within the full sample and the sample of respondents who indicated past 30 day nicotine/tobacco use at least once during the 3 waves of the study.

Tobacco Use Disorder Symptoms (past-year)				Tobacco helps me feel better if I've been feeling down			
Frequently crave tobacco		My tobacco use is out of control		Wave 1		Wave 2	
Wave 1	Wave 2	Wave 3	Wave 1	Wave 2	Wave 3	Wave 1	Wave 2
Full Sample (n = 7595)	1.8%	2.7%	3.5%	0.7%	2.0%	2.5%	4.5%
Past 30 Day users (n = 1225)	11.3%	16.9%	20.8%	4.3%	12.7%	14.5%	25.3%
Using tobacco helps me think better				I usually want to use tobacco right after I wake up			
Wave 1		Wave 2		Wave 1		Wave 2	
Full Sample (n = 7595)	1.5%	3.1%	3.2%	0.7%	1.9%	0.8%	2.0%
Past 30 Day users (n = 1225)	9.1%	18.7%	18.6%	4.2%	11.6%	5.0%	13.3%
Cronbach's alpha for TUD symptoms were .875 for Wave 1, .888 for Wave 2, and .912 for Wave 3							
Substance Use Disorder Symptoms (past-year)				Kept using alcohol or other drugs even though it was causing problems			
Spent a lot of time either getting alcohol or other drugs		Spent a lot of time using or recovering from alcohol or other drugs		Wave 1		Wave 2	
Wave 1	Wave 2	Wave 3	Wave 1	Wave 2	Wave 3	Wave 1	Wave 2
Full Sample (n = 7595)	2.8%	4.3%	5.7%	1.9%	1.9%	1.4%	2.3%
Past 30 Day users (n = 1225)	14.5%	20.6%	22.7%	9.7%	7.7%	7.5%	8.7%
Use of alcohol or other drugs caused you to reduce your involvement in activities				Used alcohol or other drugs to stop being sick or avoid withdrawal problems			
Wave 1		Wave 2		Wave 1		Wave 2	
Full Sample (n = 7595)	1.2%	1.9%	2.0%	3.6%	3.8%	1.2%	1.4%
Past 30 Day users (n = 1225)	5.8%	8.9%	7.5%	10.9%	8.1%	4.7%	5.2%
Cronbach's alpha for SUD symptoms were .794 for Wave 1, .775 for Wave 2, and .776 for Wave 3							

Notes: n = unweighted sample size; Percentages and means incorporate longitudinal survey weights for Wave 3; SE = standard error; TUD = tobacco use disorder; SUD = substance use disorder.

Table 3.

Mean past-year TUD and SUD symptom scores across the top ten different patterns of past 30-day nicotine/tobacco use between Population Assessment of Tobacco and Health (PATH) Study Wave 1, 2 and 3 (n = 7,595)

		Total	30-day users		TUD Wave 2 score		SUD Wave 2 score		TUD w2-w1		SUD w2-w1		
	n	%	%		Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)	
Past 30 day nicotine/tobacco use for wave 1 (w1) and wave 2 (w2) ^a													
	(w1) No use; (w2) No use	6820	91.07	--		0.011	0.002	0.094	0.006	0.008	0.002	0.035	0.006
	(w1) No use; (w2) Other tobacco use only	119	1.62	18.2		0.499	0.173	0.890	0.174	0.475	0.175	0.534	0.186
	(w1) No use; (w2) E-cigarette use only	102	1.43	16.1		0.019	0.021	0.475	0.091	0.019	0.021	0.377	0.094
	(w1) No use; (w2) Cigarette use only	65	0.88	9.93		1.263	0.274	0.551	0.123	1.183	0.272	0.294	0.113
	(w1) Other tobacco use only; (w2) No use	33	0.42	4.68		0.106	0.104	0.546	0.242	-0.438	0.292	-0.441	0.443
	(w1) No use; (w2) Cigarette use & Other tobacco use	31	0.44	4.87		1.495	0.447	1.567	0.422	1.495	0.447	0.947	0.479
	(w1) E-cigarette use only; (w2) No use	29	0.38	4.30		0.000	---	0.312	0.152	0.000	---	-0.070	0.186
Past 30 day use for wave 1 (w1), wave 2 (w2), and Wave 3 (w3) ^b													
	(w1) No use; (w2) No use; (w3) No use	6370	85.17	--		0.004	0.002	0.094	0.006	0.003	0.002	0.045	0.007
	(w1) No use; (w2) No use; (w3) E-cigarette use only	147	2.05	13.8		0.006	0.006	0.365	0.081	-0.018	0.018	0.187	0.090
	(w1) No use; (w2) No use; (w3) Other tobacco use only	129	1.75	11.8		0.603	0.138	0.760	0.139	0.603	0.138	0.548	0.156
	(w1) No use; (w2) E-cigarette use only; (w3) No use	62	0.83	5.64		0.000	---	0.294	0.130	0.000	---	0.239	0.134
	(w1) No use; (w2) Other tobacco use only; (w3) No use	56	0.79	5.38		0.031	0.032	0.332	0.099	-0.016	0.058	0.020	0.131
	(w1) No use; (w2) No use; (w3) Cigarette use only	49	0.68	4.62		1.003	0.285	0.481	0.167	1.003	0.285	0.256	0.169
	(w1) No use; (w2) Other tobacco use only; (w3) Other tobacco use only	37	0.45	3.08		0.462	0.243	0.838	0.261	0.462	0.243	0.487	0.287
(w1) No use; (w2) No use; (w3) Dual use	34	0.43	2.91		1.062	0.348	0.748	0.232	1.062	0.348	0.702	0.220	

		Total	30-day users		TUD Wave 2 score		SUD Wave 2 score		TUD w2-w1		SUD w2-w1	
	n	%	%		Mean	(SE)	Mean	(SE)	Mean	(SE)	Mean	(SE)
(w1) No use; (w2) No use; (w3) E-cigarette Use & Other tobacco use	28	0.43	2.91		0.304	0.288	0.433	0.147	0.198	0.311	0.123	0.198
(w1) No use; (w2) No use; (w3) Cigarette Use & Other tobacco use only	28	0.42	2.85		1.134	0.309	0.810	0.203	1.059	0.316	0.343	0.400
(w1) No use; (w2) Cigarette use only; (w3) No use	24	0.31	2.11		0.000	---	0.369	0.275	0.000	---	-0.002	0.299

Note: n = unweighted sample size; Percentages and means incorporate longitudinal survey weights for Wave 3; SE = standard error; w1 = PATH Study Wave 1; w2 = PATH Study Wave 2; w3 = PATH study Wave 3; --- = all respondents had a score of 0; TUD = tobacco use disorder; SUD = substance use disorder; **Dual use = e-cigarette and cigarette use.**

^aThis includes the ten most common patterns out of the possible 64 different patterns.

^bThis includes the ten most comment patterns out of the possible 512 different patterns.

Table 4.

Examining the association between past 30 day nicotine/tobacco use at Wave 1 and Wave 2 on changes in the number of past-year TUD and SUD symptoms ($n = 7,595$) from the Population Assessment of Tobacco and Health (PATH) Study

Full sample that includes non-nicotine/tobacco users at w1 and w2 ($n = 7,595$)		TUD Wave 2 score		SUD Wave 2 score		TUD Difference Score		SUD Difference Score w2-w1	
Past 30 day nicotine/tobacco use for w1 and w2		b^I	(SE)	b^I	(SE)	b^I	(SE)	b^I	(SE)
Constant		0.048	0.031	0.010	0.202	0.031	0.032	0.068	0.055
(w1) Past 30 day cigarette use		0.076	0.225	-0.059	0.163	-0.625**	0.231	-0.201	0.227
(w1) Past 30 day e-cigarette use		0.104	0.169	-0.059	0.177	0.026	0.206	-0.297	0.221
(w1) Past 30 day other tobacco use		0.191	0.142	-0.265	0.130	-0.222	0.159	-0.585*	0.233
(w2) Past 30 day cigarette use		1.323***	0.150	0.530***	0.112	1.187***	0.149	0.214	0.150
(w2) Past 30 day e-cigarette use		-0.102	0.082	0.290***	0.107	-0.097	0.092	0.231	0.129
(w2) Past 30 day other tobacco use		0.344**	0.122	0.457***	0.051	0.296*	0.124	0.410***	0.125
(w1) TUD Wave 1 score		0.492***	0.065	---	---	---	---	---	---
(w1) SUD Wave 1 score		---	---	0.221***	0.051	---	---	---	---
Restricted sample that includes only past 30 day nicotine/tobacco users at w1 or w2 ($n = 775$)		TUD Wave 2 score		SUD Wave 2 score		TUD Difference Score (w2-w1)		SUD Difference Score w2-w1	
Past 30 day nicotine/tobacco use for w1 and w2		b^I	(SE)	b^I	(SE)	b^I	(SE)	b^I	(SE)
Constant		0.416	0.354	-0.313	0.449	0.344	0.390	0.281	0.510
(w1) Past 30 day cigarette use		0.200	0.248	-0.114	0.210	-0.551*	0.263	-0.279	0.238
(w1) Past 30 day e-cigarette use		0.160	0.177	-0.090	0.166	0.032	0.213	-0.328	0.215
(w1) Past 30 day other tobacco use		0.215	0.167	-0.232	0.176	-0.256	0.188	-0.508*	0.230
(w2) Past 30 day cigarette use		1.326***	0.162	0.472**	0.161	1.146***	0.169	0.097	0.173
(w2) Past 30 day e-cigarette use		-0.140	0.134	0.149	0.129	-0.233	0.150	0.066	0.155
(w2) Past 30 day other tobacco use		0.349*	0.155	0.395***	0.111	0.201	0.175	0.326*	0.138
(w1) TUD Wave 1 score		0.389***	0.074	---	---	---	---	---	---
(w1) SUD Wave 1 score		---	---	0.243***	0.075	---	---	---	---

Notes:

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100' > .001
d

10' > d
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unweighted sample size; All analyses incorporate longitudinal survey weights for Wave 3; SE = standard error; b = unstandardized regression coefficient; w1 = PATH Study Wave 1; w2 = PATH Study Wave 2; TUD = tobacco use disorder; SUD = substance use disorder.

All ordinary least squares regression models control for sex, race, Hispanic ethnicity, age of respondent, household income, U.S. region, lifetime alcohol use, lifetime marijuana use, lifetime nonmedical prescription drug use, lifetime illicit drug use, whether past-year non-nicotine/tobacco users had a history of e-cigarette use prior to Wave 1, whether past-year non-tobacco users had a history of cigarette use prior to Wave 1, and whether past-year non-nicotine/tobacco users had a history of other tobacco use prior to Wave 1.

Table 5.

Examining the association between past 30 day nicotine/tobacco use at Wave 1, Wave 2, and Wave 3 on changes in the number of past-year TUD and SUD symptoms (n = 7,595) from the Population Assessment of Tobacco and Health (PATH) Study

Full sample that includes non-nicotine/tobacco users at w1, w2, and w3 (n = 7,595)				TUD Difference Score w3-w1			
	TUD Wave 3 score	SUD Wave 3 score	(SE)	b ^T	(SE)	b ^I	(SE)
Past 30 day nicotine/tobacco use for Wave 1 (w1) to Wave 3 (w3)							
Constant	0.026	0.041	0.001	0.042	0.019	0.065	0.053
(w1) Past 30 day cigarette use	-0.225	0.205	-0.141	0.130	-1.026***	-0.333	0.182
(w1) Past 30 day e-cigarette use	0.017	0.167	0.067	0.119	-0.049	-0.226	0.184
(w1) Past 30 day other tobacco use	0.001	0.160	0.138	0.127	-0.444*	-0.303	0.204
(w2) Past 30 day cigarette use	0.229	0.124	-0.175	0.092	0.386*	-0.496***	0.147
(w2) Past 30 day e-cigarette use	0.051	0.095	0.128	0.089	0.034	0.097	0.144
(w2) Past 30 day other tobacco use	0.129	0.095	0.082	0.076	0.148	0.064	0.108
(w3) Past 30 day cigarette use	1.148***	0.137	0.293***	0.085	1.124***	0.349**	0.112
(w3) Past 30 day e-cigarette use	-0.021	0.057	0.133*	0.052	-0.017	0.094	0.074
(w3) Past 30 day other tobacco use	0.491***	0.116	0.427***	0.082	0.507***	0.505***	0.096
(w1) TUD Wave 1 score	0.219**	0.074	---	---	---	---	---
(w2) TUD Wave 2 score	0.232***	0.042	---	---	---	---	---
(w1) SUD Wave 1 score	---	---	0.052	0.036	---	---	---
(w2) SUD Wave 2 score	---	---	0.154***	0.033	---	---	---
Restricted sample that includes only past 30 day nicotine/tobacco users at w1, w2, or w3 (n = 1,225)							
	TUD Wave 3 score	SUD Wave 3 score	(SE)	b ^T	(SE)	b ^I	(SE)
Past 30 day nicotine/tobacco use for Wave 1 (w1) to Wave 3 (w3)							
Constant	0.019	0.275	-0.066	0.185	0.072	0.296	0.264
(w1) Past 30 day cigarette use	-0.233	0.215	-0.133	0.135	-1.030***	-0.328	0.185
(w1) Past 30 day e-cigarette use	0.031	0.178	0.081	0.119	-0.035	-0.182	0.181
(w1) Past 30 day other tobacco use	0.027	0.171	0.135	0.126	-0.409	-0.250	0.204
(w2) Past 30 day cigarette use	0.211	0.126	-0.149	0.101	0.394*	-0.491***	0.138

Full sample that includes non-nicotine/tobacco users at w1, w2, and w3 (n = 7,595)									
Past 30 day nicotine/tobacco use for Wave 1 (w1) to Wave 3 (w3)									
	b^I	(SE)	b^I	(SE)	TUD Wave 3 score	b^I	(SE)	b^I	(SE)
(w2) Past 30 day e-cigarette use	0.059	0.104	0.138	0.091	0.002	0.119	0.111	0.139	0.139
(w2) Past 30 day other tobacco use	0.154	0.095	0.115	0.088	0.161	0.105	0.107	0.117	0.117
(w3) Past 30 day cigarette use	1.139***	0.132	0.296***	0.085	1.105***	0.153	0.329**	0.115	0.115
(w3) Past 30 day e-cigarette use	0.005	0.083	0.143*	0.068	-0.057	0.082	0.079	0.085	0.085
(w3) Past 30 day other tobacco use	0.551**	0.109	0.457**	0.099	0.519***	0.118	0.552***	0.110	0.110
(w1) TUD Wave 1 score	0.204**	0.073	---	---	---	---	---	---	---
(w2) TUD Wave 2 score	0.254***	0.047	---	---	---	---	---	---	---
(w1) SUD Wave 1 score	---	---	0.045	0.047	---	---	---	---	---
(w2) SUD Wave 2 score	---	---	0.129**	0.048	---	---	---	---	---

Notes:

* p < .05

** p < .01

*** p < .001

n = unweighted sample size; All analyses incorporate longitudinal survey weights for Wave 3; SE = standard error; b = unstandardized regression coefficient; w1 = PATH Study Wave 1; w2 = PATH Study Wave 2; w3 = PATH Study Wave 3; TUD = tobacco use disorder; SUD = substance use disorder.

/ All ordinary least squares regression models control for sex, race, Hispanic ethnicity, age of respondent, household income, U.S. region, lifetime alcohol use, lifetime marijuana use, lifetime nonmedical prescription drug use, lifetime illicit drug use, whether past-year non-nicotine/tobacco users had a history of e-cigarette use prior to Wave 1, whether past-year non-tobacco users had a history of cigarette use prior to Wave 1, and whether past-year non-nicotine/tobacco users had a history of other tobacco use prior to Wave 1.