

E-CIGARETTE QUITTING INTEREST AND CESSATION BEHAVIOR AMONG E-
CIGARETTE USERS: FINDINGS FROM THE POPULATION ASSESSMENT OF
TOBACCO AND HEALTH (PATH) WAVES 2 (2014-2015) AND 3 (2015-2016)

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ABSTRACT OF THE THESIS

E-cigarette quitting interest and cessation behavior among e-cigarette users: Findings from the Population Assessment of Tobacco and Health (PATH) Waves 2 (2014-2015) and 3 (2015-2016)

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Over 10 million adults report use of e-cigarettes, with approximately 3.6 million reporting daily use. Few studies to date have examined e-cigarette cessation interest and related behaviors among e-cigarette users. The current study aimed to describe past year attempts to stop or reduce e-cigarette use and to investigate individual characteristics and e-cigarette use characteristics associated with past year e-cigarette quit attempts using data from the Population Assessment of Tobacco and Health (PATH) Study Waves 2 and 3. On average, study participants had an e-cigarette dependence level of 1.9 out of 5 (95% CI [1.8, 2.0]), and reported an average of 19.9 days of e-cigarette use in the past month (95% CI [19.1, 20.7]). Over 25% of participants attempted to quit e-cigarettes in the past year (95% CI [24.0, 28.7]). The likelihood of attempting to quit e-cigarettes was associated with reporting problematic use of at least one non-nicotine substance (OR: 1.8; CI: 1.1, 2.8), higher e-cigarette dependence (OR: 1.3; CI: 1.1, 1.6) and higher interest in quitting e-cigarettes (OR: 1.2; CI: 1.2, 1.3). The current study adds support to claims that e-cigarette users want to quit vaping and highlights the need for continued research on e-cigarette cessation.

Table of Contents

Abstract.....	ii
List of Tables.....	v
Introduction.....	1
Method.....	7
Participants.....	7
Measures.....	7
Data analytic strategy.....	11
Results.....	14
Participant Characteristics at Wave 2.....	14
E-cigarette, Mental Health, and Substance Use Characteristics at Wave 2.....	14
Attempts to Quit E-cigarettes and Cessation Strategies Used at Wave 3.....	15
Association between Likelihood of Attempting to Quit E-cigarettes in the Year Prior to Wave 3 and Participant Characteristics at Wave 2 among dual/poly tobacco users.....	15
Association between Likelihood of Attempting to Quit E-cigarettes in the Year Prior to Wave 3 and Participant Characteristics at Wave 2.....	15
Discussion.....	17
Appendix A.....	25
Appendix B.....	26
Appendix C.....	27
Appendix D.....	28
Appendix E.....	29

Appendix F.....	30
Appendix G.....	31
Appendix H.....	32
Appendix I.....	33
Appendix J.....	34
Appendix K.....	35
Acknowledgement of Previous Publications.....	36
Bibliography.....	37

List of Tables

Table 1: Baseline sample demographic characteristics at Wave 2.....	25
Table 2: E-cigarette, Mental Health, and Substance Use Characteristics at Wave 2.....	26
Table 3: Formal and informal e-cigarette cessation strategies endorsed by e-cigarette users at Wave 3.....	27
Table 4: Association between attempting to quit e-cigarettes in the year prior to Wave 3 and interest in quitting e-cigarettes at Wave 2 among dual/poly tobacco users.....	28
Table 5: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and perceived confidence in quitting e-cigarettes at Wave 2 among dual/poly tobacco users.....	29
Table 6: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and the number of reasons for e-cigarette use among dual/poly tobacco users.....	30
Table 7: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and cigarette use frequency at Wave 2 among dual/poly tobacco users.....	31
Table 8: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-cigarette dependence at Wave 2 among dual/poly tobacco users	32
Table 9: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and mental health symptoms and substance use at Wave 2.....	33
Table 10: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-liquid flavor use at Wave 2.....	34

Table 11: Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-cigarette use frequency at Wave 2.....	35
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Introduction

E-cigarettes are devices that deliver nicotine to a user in the form of an aerosol (Grana et al., 2013). The first mainstream production of an e-cigarette, introduced by Chinese pharmacist, Hon Lik, became popular in the United States in the mid-2000s (USDHHS, 2016). By 2017, the e-cigarette industry grew to over 433 brands available for purchase, over 15,000 e-liquid flavors from which e-cigarette users could choose, and varying concentrations of nicotine (Hsu et al., 2018). Currently, in the United States over 4.5% of adults, or over 10.8 million adults, report use of e-cigarettes (“vaping”; Mirbolouk et al., 2018). Approximately 30% are former combustible cigarette smokers, 58.8% are dual users, and 11.4% are exclusive e-cigarette users (MMWR Morb Mortal Wkly, 2016).

Many adults report using e-cigarettes as a tool for quitting smoking and as a safer alternative to smoking combustible cigarettes (Goniewicz et al., 2013; Grana et al., 2013; Patel et al., 2016). Evidence suggests that e-cigarettes are *safer* than combustible cigarettes (Farsalinos, 2018). Because of their relative recency on the market and the continued and quick evolution of e-cigarette devices, it is challenging to accurately characterize e-cigarette use and long-term health effects; however, there is no evidence that e-cigarettes are completely safe. E-cigarette use is associated with health risks including nicotine addiction, risk of cardiovascular disease, and respiratory illness (USDHHS, 2016).

While e-cigarette use may initially increase the likelihood of quitting combustible cigarettes (Brown et al., 2014; Coleman et al., 2018; Hajek et al., 2019; Verplaetse et al., 2018; Young-Wolff et al., 2018), adults may continue to use e-cigarettes for long periods

of time (Coleman et al., 2018; Dawkins et al., 2013; Du et al., 2019) and at high frequencies (Biener & Hargraves, 2015; Hitchman et al., 2015). One large randomized controlled trial in the UK comparing behavioral counseling plus either e-cigarettes or nicotine replacement therapy found that using e-cigarettes may increase successful abstinence from combustible cigarettes (Hajek et al., 2019). However, approximately 80% of those who were randomized to the e-cigarette condition and who successfully quit combustible cigarettes reported continued use of e-cigarettes one year later (Hajek et al., 2019). In a US population-based survey, daily or frequent e-cigarette use was associated with recently having quit smoking or being a former combustible cigarette smoker (Coleman et al., 2017). A follow-up study revealed that daily e-cigarette use was associated with continued e-cigarette use one year later (Coleman et al., 2018). Together, evidence suggests that among combustible cigarette smokers or former smokers, e-cigarettes may contribute to better combustible cigarette cessation outcomes, however, this may contribute to daily (or more frequent) e-cigarette use.

There are fewer e-cigarette users who report no history of combustible cigarette smoking. However, this is one group for whom any e-cigarette use only increases health risks, such as nicotine addiction and risk of cardiovascular or pulmonary disease (USDHHS, 2016). While, on average, only 11% of e-cigarette users report exclusive e-cigarette use (i.e., no history of combustible smoking), among young adults, almost half of e-cigarette users report exclusive e-cigarette use, with no combustible smoking history (Mirbolouk et al., 2018). According to a US population-based survey, e-cigarette users with no history of smoking report lower frequency e-cigarette use (i.e., fewer days of smoking; Mirbolouk et al., 2018). While exclusive e-cigarette use is less prevalent and

may be associated with reduced risks due to lower frequency use, any e-cigarette use may contribute to risk of negative health consequences.

One reason adults may continue to use e-cigarettes, regardless of combustible smoking history, is due to nicotine dependence. There is evidence that e-cigarette users report dependence on e-cigarettes (Case et al., 2018; Du et al., 2019; Etter, 2019; Foulds et al., 2015; Rostron et al., 2016), and many report cravings to use e-cigarettes (Dowd et al., 2019). Formal intervention may be necessary for individuals to successfully quit vaping. Further, given the growing evidence that e-cigarette users may be interested in quitting vaping (Etter, 2019; Garey et al., 2019), there is a need to better understand e-cigarettes use and naturally occurring cessation behavior in adult vapers. Studies have examined changes in the use of e-cigarettes and combustible cigarettes (Berry et al., 2019; Coleman et al., 2018), but studies generally fail to acknowledge the importance of eventual e-cigarette cessation.

While some studies have suggested that e-cigarette users report no intention to stop using e-cigarettes (Harrell et al., 2015), others have demonstrated that e-cigarette users have interest in quitting e-cigarettes in the near future (Etter, 2019; Garey et al., 2019; Rosen & Steinberg, 2019). E-cigarette users have even reported past attempts to quit e-cigarettes (Dowd et al., 2019; Garey et al., 2019; Rosen & Steinberg, 2019). There has been a lack of clarity regarding e-cigarette users' interest in stopping or reducing e-cigarette use, and attempts to do so.

An immense body of research has demonstrated challenges in smoking cessation for combustible cigarette smokers, and has begun to identify factors that may help promote cessation behavior. Studies of combustible cigarette smokers and cessation may

provide some information about factors that may be associated with e-cigarette cessation. Among non-treatment seeking adults who smoke combustible cigarettes, greater motivation and increased confidence in quitting were associated with increased likelihood of making a quit attempt (Jardin & Carpenter, 2012). Interest in or intent to quit smoking combustible cigarettes has also been linked to increased likelihood of making a quit attempt in combustible cigarette smokers with plans to quit in the near future (Hughes et al., 2014). A cross-cultural, longitudinal study of non-treatment seeking combustible cigarette smokers found that risk-minimizing beliefs (i.e., beliefs that smoking is not very harmful) were associated with lower likelihood of making a quit attempt (Borland et al., 2009). Together, these findings suggest that intent to quit, confidence about quitting, and beliefs about smoking may promote or inhibit attempts to quit smoking.

Combustible cigarette smokers with mental health concerns, including substance use, may have reduced likelihood of successful combustible cigarette cessation. Adults with mental health concerns are equally likely to make quit attempts when compared to those without mental health concerns (Tulloch et al., 2016), however, these attempts are less likely to be successful (Glasheen et al., 2014). A similar pattern of results was found in a previously conducted literature review of concurrent treatment of smoking and substance use (Richter & Arnsten, 2006). Specifically, findings suggested that adults who drink and smoke are as likely to attempt to quit smoking but are less likely to be successful (Richter & Arnsten, 2006). Relatedly, a previously conducted systematic review of population-based studies found evidence (in most studies) of a relationship between higher combustible cigarette dependence and reduced likelihood of making a quit attempt (Vangeli et al., 2011). Further, the same review highlighted that heavier

smoking, as measured by more combustible cigarettes smoked per day, was also associated with reduced likelihood of making an attempt to quit smoking in most studies (Vangeli et al., 2011). Findings suggest that mental health concerns, substance use, and more severe tobacco use are associated with worse cessation outcomes in combustible cigarette smokers.

There is strong evidence to suggest that motivation, self-efficacy, mental health, and substance use characteristics will inhibit or promote cessation behavior in combustible cigarette smokers. To date, limited research has begun to examine these relationships in e-cigarette users. This study aimed to address gaps in our understanding of e-cigarette cessation, including users' interest in quitting e-cigarettes, e-cigarette quitting behavior, and factors that are associated with increased likelihood of making an e-cigarette quit attempt. The current study sought to understand factors that may be associated with the likelihood of making an attempt to quit e-cigarettes, including other substance use, mental health concerns, e-cigarette use characteristics.

As such, this study included three specific aims: 1) to describe past year attempts to stop or reduce e-cigarette use, including the strategies most commonly employed by e-cigarette users, 2) to investigate characteristics associated with the likelihood of making a past year e-cigarette quit attempt among dual/poly users of e-cigarettes and another tobacco product; 3) to investigate characteristics associated with the likelihood of making a past year e-cigarette quit attempt among e-cigarette users. I hypothesized that, among dual/poly tobacco users who endorsed use of e-cigarettes, greater interest in quitting vaping, greater perceived ability to quit, fewer reasons for using e-cigarettes, less e-cigarette dependence, and greater frequency of cigarette use would be associated with a

greater likelihood of making an attempt to quit vaping. Further I hypothesized that among e-cigarette users, greater e-cigarette use frequency, problematic substance use, greater mental health symptoms, and exclusive non-tobacco flavor use would be associated with greater likelihood of making an e-cigarette quit attempt.

Method

Participants

I examined data from the Population Assessment of Tobacco and Health (PATH) Public Use Adult Questionnaire at Waves 2 (2014-2015) and 3 (2015-2016). The PATH study is a national and longitudinal study of adults in the United States which aims to understand the implications of tobacco use on health over time. Non-institutionalized youth and adults were recruited to participate in the original study (Hyland et al., 2018). Participants were selected from households, within geographic areas that were oversampled for target variables, including tobacco users, young adults, and Black/African American adults (Hyland et al., 2018). For the current study, I included current (past month) adult (18 and over) established e-cigarette users (i.e., individuals reporting “regular” use) at Waves 2 and 3 who participated in both waves of data collection.

Measures

Measures assessed at Wave 2.

Demographics. Participants provided basic demographic information, including age, gender, race, ethnicity and household income. In an effort to protect the confidentiality of participants, continuous demographic variables (e.g., age) were recoded into categorical variables, and response options for categorical variables (e.g., race) were collapsed into fewer categories by the PATH Study team before data were made public.

E-cigarette use status. Consistent with definitions used elsewhere (e.g., Rodu & Plurphanswat, 2017), individuals were considered current, established e-cigarette users if they met all of the following criteria: having ever used an e-cigarette, having ever used e-

cigarettes fairly regularly, and now use e-cigarettes. These criteria are similar to those commonly used to determine combustible cigarette smoking status (e.g., in the National Health Interview Survey), which defines current, established combustible cigarette use as ever use of combustible cigarettes, lifetime use of at least 100 combustible cigarettes, and current use of combustible cigarettes. Due to differences in the way e-cigarettes (compared to combustible cigarettes) are used, a subjective rating of “regular” e-cigarette use was used by the PATH study team to differentiate experimental e-cigarette users from established e-cigarette users.

E-cigarette quitting interest. Participants rated their level of interest in stopping use of e-cigarettes using a scale of 1 (“not at all interested”) to 10 (“extremely interested”). By design of the PATH study, only dual/poly-tobacco users who also endorsed use of e-cigarettes responded to this question.

Perceived confidence in success with quitting e-cigarettes. Participants who endorsed interest in quitting e-cigarettes within the next 6 months rated their likelihood of being successful if they tried to stop using e-cigarettes completely, using a scale of 1 (“not at all likely”) to 4 (“very likely”). By design of the PATH study, only dual/poly-tobacco users who also endorsed use of e-cigarettes responded to this question.

Reasons for using e-cigarettes. Several questions assessed reasons for using e-cigarettes, including “they are affordable,” “they might be less harmful to me than cigarettes,” and “it comes in flavors I like.” Respondents provided an affirmative or negative response for each item and I derived a total score by summing affirmative responses, with a total possible score ranging from 0 to 13. By design of the PATH study, only dual/poly-tobacco users who also endorsed use of e-cigarettes responded to this

question.

Other substance use. Participants indicated whether they used alcohol, marijuana, painkillers, cocaine/crack, stimulants, and heroin/inhalants/hallucinogens in the past year. By design of the PATH study, only individuals who reported use of two or more substances were queried about whether any substance “caused problems” for them. I derived a single item to describe whether individuals reported problematic use of any or none of the abovementioned substances.

Mental health symptoms. Using nine questions derived from the Global Appraisal of Individual Needs – Short Screener (GAIN-SS), participants indicated whether they “had a significant problem with” mental health concerns within the past year (Dennis et al., 2006, 2008). Sample items include: “feeling very trapped, lonely, sad, blue, depressed or hopeless about the future,” “sleep trouble – such as bad dreams, sleeping restlessly or falling asleep during the day,” or “feeling very anxious, nervous, tense, scared, panicked or like something bad was going to happen.” Separate index scores were calculated for past year externalizing symptoms (i.e., symptoms associated with ADHD, impulsivity, conduct disorders) and internalizing symptoms (i.e., symptoms associated with depression, anxiety, trauma), with total scores ranging from 0 to 5 for externalizing symptoms and from 0 to 4 for internalizing symptoms. Higher scores reflect a higher symptom count and a greater likelihood of diagnosis of a behavioral health disorder.

Cigarette use frequency. Self-identified combustible cigarette smokers indicated whether they currently smoked cigarettes “daily,” “some days” or “not at all.” Daily cigarette smokers were assumed to have used cigarettes on all of the past 30 days. “Some

day” cigarette smokers reported the number of days they used cigarettes during the last 30 days.

E-cigarette use frequency. Participants indicated whether they currently used e-cigarettes “daily,” “some days” or “not at all.” Daily e-cigarette users were assumed to have used e-cigarettes on all of the past 30 days. “Some day” e-cigarette users reported the number of days they used e-cigarettes during the last 30 days.

Dependence on e-cigarettes. A combination of 16 items derived from the Wisconsin Inventory of Smoking Dependence Motive inventory (Piper et al., 2004), the Nicotine Dependence Syndrome Scale (Shiffman et al., 2004), and the DSM-5 (American Psychiatric Association, 2013), adapted for use among e-cigarette users, was used to measure e-cigarette dependence, consistent with methods used elsewhere to characterize e-cigarette dependence in the PATH Study sample (Strong et al., 2017). Sample items include: “Using e-cigarettes really helps me feel better if I’ve been feeling down” and “I often smoke without thinking about it.” All items were rated on a scale of 1 (“not true of me at all”) to 5 (“extremely true of me”). A mean score was calculated across all items, consistent with methods used elsewhere (Strong et al., 2017). Higher scores reflect higher e-cigarette dependence. By design of the PATH study, only dual/poly-tobacco users who also endorsed use of e-cigarettes responded to these questions. Internal consistency reliability of this measure was strong ($\alpha = 0.95$) at Wave 2.

E-cigarette flavor use. Individuals provided information about e-cigarette flavor use by responding to a single item: “Is your regular brand flavored to taste like menthol, mint, clove, spice, candy, fruit, chocolate, alcohol (such as wine or cognac), or other sweets?” Affirmative responses indicate use of a non-tobacco flavor. By design of the

PATH study, only dual/poly-tobacco users who also endorsed use of e-cigarettes responded to this question.

Measures assessed at Wave 3.

E-cigarette quitting effort. At Wave 3, e-cigarette users indicated whether they made any attempt to quit using e-cigarettes in the past year (between Waves 2 and 3), including whether they “tried to quit completely” or “tried to quit gradually by cutting back.” Responses were dichotomized for the current analyses (i.e., any attempts vs. no attempts). Reported attempts to quit e-cigarettes were unsuccessful by design of the PATH study. Participants were only asked about attempts to quit e-cigarettes between Waves 2 and 3 if they reported current e-cigarette use at Wave 3.

Formal and informal e-cigarette cessation strategies. E-cigarette users responded to questions about their use of e-cigarette-specific formal and informal cessation strategies during their last e-cigarette quit attempt during the past year. Sample items include: relying on support from family and friends, using counseling or self-help materials, and using nicotine replacement or other FDA-approved smoking cessation medications.

Data Analytic Strategy

To account for the complex survey design and sampling procedures described above, I used sample weights across all analyses (Hyland et al., 2018), as well as replicate weights and balanced repeated replication for variance estimation. All weights were provided by the PATH Study team. I conducted all analyses with SAS (version 9.4). Instances of missing data were detected, ranging from 1614 missing observations (NRT for e-cigarette cessation) to 66 missing observations (age). Reasons for missing data

include participant nonresponse, uncorrected errors in survey administration, and questions being asked of certain subsets of the sample. Descriptive statistics included all available data for each measure. I used listwise deletion for logistic regression analyses, given the relatively large sample sizes.

Descriptive statistics. To address the first aim, I reported descriptive statistics regarding past year attempts to stop or reduce use of e-cigarettes and the strategies most commonly employed by e-cigarette users at Wave 3. All wave sample weights were applied to the current analyses.

Selection of model covariates for binary logistic regression analyses. I considered theoretically relevant demographic variables for inclusion as model covariates across all binary logistic regression analyses. First, I assessed candidate covariates (i.e., age, gender, race, ethnicity, and household income) for univariate association with the primary outcome. I retained variables that were associated with the primary outcome variable at the $p < .25$ level (i.e., gender, race and ethnicity; Agresti, 2003). Inclusion of gender, race, and ethnicity improved overall model fit, based on a lower AIC, across all analyses.

Logistic regression analyses. To address the second aim investigating characteristics associated with the likelihood of making a past year e-cigarette quit attempt among dual/poly tobacco users, I used separate binary logistic regression analyses to predict the likelihood of making a past year e-cigarette quit attempt at Wave 3 as a function of each of the following individual characteristics at Wave 2: interest in quitting vaping, perceived ability to quit, reasons for using e-cigarettes, e-cigarette dependence, and cigarette smoking frequency. All models also included gender, race, and

ethnicity as independent variables. I applied all wave weights to the current analyses and used listwise deletion for these logistic regression analyses.

To address the third aim predicting the likelihood of making an e-cigarette quit attempt as a function of e-cigarette use characteristics, I used a binary logistic regression analysis to predict the likelihood of making a past year e-cigarette quit attempt at Wave 3 as a function of each of the following variables at wave 2: problematic substance use, mental health symptoms, gender, race, and ethnicity. I used a separate binary logistic regression analysis to predict the likelihood of making a past year e-cigarette quit attempt at Wave 3 as a function of each of the following variables at wave 2: e-cigarette use frequency, and exclusive non-tobacco flavor use. All models also included gender, race, and ethnicity as independent variables. I applied all wave weights to the current analysis and used listwise deletion for these logistic regression analyses. I ran separate analyses due to sample size constraints associated with listwise deletion when all variables were included in one model. I included unweighted sample sizes, weighted population estimates, and 95% confidence intervals throughout.

Results

The original sample included 1638 adult e-cigarette users reporting e-cigarette use at Waves 2 and 3.

Participant Characteristics at Baseline (Wave 2)

The majority of participants were between 18 and 34 years old (51.3%), male (55.4%), not Hispanic (89.4%), and White (81.9%). Most participants had a household income over \$50k (64.7%). Additional demographic information is presented in Table 1.

E-cigarette, Mental Health, and Substance Use Characteristics at Baseline (Wave 2)

Descriptive statistics included all available data, which resulted in inconsistent sample sizes across variables. Additional e-cigarette, mental health, and substance use information, including sample sizes for each variable, is presented in Table 2.

On average, dual/poly tobacco users had an e-cigarette dependence level of 1.9 out of 5 (95% CI [1.8, 2.0]), had moderate interest in quitting e-cigarettes (3.6 out of 10; 95% CI [3.4, 3.9]), and of those who reported plans to quit e-cigarettes in the next 6 months, participants reported high levels of confidence in their ability to succeed (3.4 out of 4; 95% CI [3.3, 3.6]). Participants endorsed 7.6 (out of 13; 95% CI [7.4, 7.7]) reasons for using e-cigarettes, on average. Of those who reported smoking cigarettes in the past year, participants endorsed smoking on 24.4 days out of the past 30 days (95% CI [23.7, 25.1]).

Among e-cigarettes users, participants reported an average of 19.9 days of e-cigarette use in the past month (95% CI [19.1, 20.7]). Study participants reported use of tobacco e-liquid flavors (22.3%, 95% CI [19.2, 25.7]) and non-tobacco flavors (e.g., mint, candy, alcohol; 77.7%, 95% CI [74.3, 80.8]) in the past 30 days. Over 44% (95%

CI [39.0, 49.7]) of e-cigarette users reported problematic use of at least one non-nicotine substance. On average, participants endorsed an average of 1.9 out of 4 (95% CI [1.8, 2.0]) GAIN-SS internalizing disorder symptoms, and an average of 1.2 out of 5 GAIN-SS externalizing disorder symptoms (95% CI [1.1, 1.2]).

Attempts to Quit E-cigarettes and Cessation Strategies Used at Wave 3

Over 25% of participants (n=1638) reported attempts to quit e-cigarettes in the past year (95% CI [24.0, 28.7]) either by quitting completely or cutting down in an effort to quit completely. Participants who reported an attempt to quit e-cigarettes completely endorsed the use of formal and informal cessation strategies (see Table 3).

Association between Likelihood of Attempting to Quit E-cigarettes in the Year Prior to Wave 3 and Participant Characteristics at Wave 2 among dual/poly tobacco users

Among dual/poly tobacco users, greater interest in quitting e-cigarettes (OR: 1.2; CI: 1.2, 1.3; n=623) at Wave 2 was associated with increased likelihood of making an attempt to quit e-cigarettes at Wave 3 (See Table 4). Greater e-cigarette dependence at Wave 2 (OR: 1.3; CI: 1.1, 1.6; n=780) was associated with increased likelihood of making an attempt to quit e-cigarettes at Wave 3 (See Table 8). Perceived ability to successfully quit e-cigarette (Table 5), and number of reasons for using e-cigarettes (Table 6) and cigarette use frequency (Table 7) at Wave 2 were not associated with increased likelihood of making an e-cigarette quit attempt at Wave 3.

Association between Likelihood of Attempting to Quit E-cigarettes in the Year Prior to Wave 3 and Participant Characteristics at Wave 2

The likelihood of attempting to quit e-cigarettes at Wave 3 was associated with reporting problematic use of at least one non-nicotine substance at Wave 2 (OR: 1.8; CI:

1.1, 2.8; See Table 9). Past year number internalizing disorder and externalizing disorder symptoms (Table 9), e-cigarette flavor use (Table 10), and frequency of e-cigarette use in the past month (Table 11) at Wave 2 were not associated with increased likelihood of making an e-cigarette quit attempt at Wave 3.

Discussion

Findings suggest that e-cigarette users have low-to-moderate levels of e-cigarette dependence and interest in quitting e-cigarettes. Further, findings suggest that over 25% of e-cigarette users made attempts to quit e-cigarettes within the past year and that approximately 85% of users endorsed use of formal and informal strategies, including social support, counseling, and FDA-approved cessation medication. These findings are consistent with prior evidence suggesting that e-cigarette users are dependent on e-cigarettes (Case et al., 2018; Du et al., 2019; Etter, 2019; Foulds et al., 2015; Rostron et al., 2016) and that approximately one-third of e-cigarette users have interest in (Etter, 2019) and are making attempts to quit vaping (Dowd et al., 2019; Garey et al., 2019).

To my knowledge, this is the first study to examine cessation methods used by a nationally representative sample of adult e-cigarette users in the United States during attempts to quit e-cigarettes. One study in Europe reported that approximately half of e-cigarette users would be interested in a variety of supports for e-cigarette cessation, including online services, medication, and support from a health professional (Etter, 2019). In the current study, only 15.2% of adult e-cigarette users who made attempts to quit e-cigarettes completely denied using any formal or informal intervention. E-cigarette users who reported attempts to quit e-cigarettes completely endorsed the use of counseling (12.2%) and support from friends and family (26.7%). Among adult e-cigarette users who reported the use of an FDA-approved cessation aid in the past year, over 75% reported the use of nicotine replacement therapy (NRT) and approximately 70% reported the use of varenicline or bupropion specifically for e-cigarettes. Among e-cigarette users who reported use of nicotine replacement in the past year and who also

attempted to quit combustible cigarettes, approximately 70% reported use of nicotine replacement for quitting e-cigarettes *and* cigarettes. This finding suggests that individuals who use nicotine replacement therapy as a combustible cigarette cessation aid may be open to using nicotine replacement to help them stop using e-cigarettes. In the current study, all reported attempts to quit e-cigarettes were unsuccessful because questions about e-cigarette cessation were only asked of participants who were still reporting e-cigarette use. These findings suggest that treatments that have strong empirical support for combustible cigarette cessation (e.g., nicotine replacement therapy) may not be effective for all e-cigarette users. However, to my knowledge no randomized controlled trials have investigated the efficacy of NRT, other cessation medications, or psychosocial interventions for e-cigarette cessation, despite these interventions serving as the gold-standard treatments for combustible cigarette cessation (USDHHS, 2008), and their potential acceptability as interventions based on the current study.

The current study is the first to my knowledge to investigate factors that are prospectively associated with attempts to quit e-cigarettes. A priori hypotheses regarding predictors of e-cigarette quit attempts were partially supported. I hypothesized that, among dual/poly tobacco users who use e-cigarettes, individuals with greater interest in quitting vaping, greater perceived ability to quit, less e-cigarette dependence and fewer reasons for using e-cigarettes (Aim 2) would be more likely to report attempts to quit e-cigarettes. Further, I hypothesized that, among e-cigarette users, non-tobacco flavor use, greater frequency e-cigarette use, problematic substance use, and greater mental health symptoms would be associated with a reduced likelihood of making attempts to quit e-cigarettes (Aim 3).

Consistent with my hypothesis, dual/poly e-cigarette users with higher interest in quitting e-cigarettes were 1.2 times more likely to make an attempt to quit e-cigarettes for every one unit increase in interest to quit. These findings are consistent with those found in studies of combustible cigarette smokers, suggesting that interest in or intent to quit is associated with future quit attempts (Hughes et al., 2014). This finding highlights a potential target for intervention. Specifically, findings suggest that interventions aimed at increasing interest in quitting (e.g., Motivational Interviewing) may contribute to increased likelihood of individuals making quit attempts. However, perceived confidence in ability to quit vaping among dual/poly e-cigarette users with interest in quitting vaping within the next six months was not significantly associated with likelihood of making an attempt to quit e-cigarettes. This mirrors findings from a review of population-based studies which failed to demonstrate a consistent relationship between confidence in ability to quit and quit attempts among combustible cigarette smokers (Vangeli et al., 2011). In the current study, participants who planned to quit within the next six months were asked to rate their confidence in their ability to quit. Though the PATH dataset does not allow us to test this hypothesis, it may be the case that confidence ratings are better predictors of success for quit attempts nearer in time (e.g., the next day or week versus in six months). This measure may be capturing perceived ability to be successful *if* one plans to make an attempt, however, many individuals may not have imminent plans to quit and many may not have made any attempts to quit at all.

Further, there was no significant association between likelihood of making an e-cigarette quit attempt and cigarette smoking frequency among dual/poly tobacco users. While combustible cigarette smoking is associated with current e-cigarette use (MMWR

Morb Mortal Wkly, 2016), it is unclear how patterns of combustible cigarette smoking may relate to attempts to quit e-cigarettes. Whereas, higher frequency combustible cigarette use may be associated with e-cigarette quit attempts (e.g., due to lack of satisfaction with the device), lower frequency combustible cigarette smoking may also be associated with e-cigarette quit attempts (e.g., due to a plan to reduce or quit all nicotine delivery products). Thus, a more nuanced assessment of these factors may be necessary to understand the association between combustible cigarette smoking and e-cigarette quit attempts.

Contrary to my hypotheses, in dual/poly tobacco users, greater e-cigarette dependence was associated with greater odds of making an e-cigarette quit attempt among individuals who reported continued e-cigarette use. Specifically, every one unit increase in e-cigarette dependence was associated with 1.3 times greater odds of making an e-cigarette quit attempt. These findings are consistent with data from a cross-sectional study of adult e-cigarette users which found that individuals reporting failed attempts to quit e-cigarettes reported higher levels of e-cigarette dependence (Garey et al., 2019). The current study adds to previous findings by observing the relationship between e-cigarette dependence and failed quit attempts in a nationally representative US sample of adults and looks prospectively at e-cigarette dependence and the likelihood of making subsequent failed attempts to quit e-cigarettes. A previously conducted systematic review of population-based studies found, in most studies, that lower dependence was associated with future quit attempts, while others reported no association (Vangeli et al., 2011). Findings from the current study suggest a slightly different pattern among e-cigarette users. There may be something unique about e-cigarette (as compared to combustible

cigarette) dependence and the relationship to cessation-related behaviors given differences in patterns of e-cigarette and dual use and the trajectory of e-cigarette use (e.g., following cigarette cessation). For example, former smokers who use e-cigarettes may ultimately be interested in quitting all nicotine delivery products, thus contributing to increased likelihood of attempts to quit e-cigarettes, however, due to dual use or recent cigarette smoking, individuals may exhibit higher levels of nicotine dependence. This may contribute to more difficulty quitting, despite making attempts to quit. Even among exclusive e-cigarette users, user and device characteristics that promote the addictiveness of e-cigarettes (e.g., frequent puffs throughout the day, higher voltage devices, higher nicotine concentration) may interfere with successful attempts to quit e-cigarettes.

Also contrary to my hypotheses, in e-cigarette users, endorsement of problematic substance use was associated with almost two times greater odds of making a (failed) e-cigarette quit attempt. The association between the likelihood of making e-cigarette quit attempts and greater severity of substance use may be explained by the fact that all attempts to quit were unsuccessful. Individuals who made successful attempts to quit would not be captured in the current study due to questions about e-cigarette cessation only being asked of participants who were still reporting use of e-cigarettes. These individuals may be less likely to report problematic substance use.

I did not observe an association between frequency of e-cigarette use and likelihood of making an e-cigarette quit attempt, as is seen in cigarette smokers (Vangeli et al., 2011). Thus, there may be certain facets of e-cigarette use (e.g., dependence) that are more strongly associated with e-cigarette quit attempts, as was observed in the current study. Other measures related to frequency of e-cigarette use, such as number of puffs per

day, may be more closely related to e-cigarette dependence and attempts to quit e-cigarettes.

Whereas previous work has found that the use of non-tobacco e-liquid flavors may be associated with increased attempts to quit combustible cigarettes, increased frequency, and increased duration of e-cigarette use in young adult combustible cigarette smokers who report interest in quitting combustible cigarettes (Chen, 2018), I did not observe a significant association between e-liquid flavor use and likelihood of making an e-cigarette quit attempt in the current study. E-cigarette users report that e-liquid flavors are related to their interest in and use of e-cigarettes, however, the current study does not provide evidence to suggest that e-liquid flavor use is associated with likelihood of making attempts to quit e-cigarettes. It may be the case that the palatability or appeal of e-cigarettes may help to transition e-cigarette users away from combustible cigarettes and help them to successfully quit smoking. Thus, the appeal of e-cigarettes, regardless of flavor used, may be associated with e-cigarette quit attempts. For example, those who find e-cigarettes to be particularly palatable may have more difficulty stopping use regardless of the chosen flavor. Thus, the specific e-liquid flavor used may not be a primary driver of attempts to quit e-cigarettes.

There are several limitations of the current study that are worth noting. First, although the current study is strengthened by the use of a large, nationally representative sample of adults in the United States, the PATH study was not designed with the current study aims in mind. The PATH study did not assess reasons for making e-cigarette quit attempts, the number of past quit attempts, or the success of a given quit attempt. For example, it is possible that attempts to quit e-cigarettes in the current study were

triggered by lack of satisfaction with e-cigarettes (followed by a return to smoking), as opposed to interest in quitting nicotine and tobacco products. Second, given that data were collected using computerized surveys, comprehensive assessment of mental health symptoms was also limited. Third, certain survey questions were only asked of subsets of participants (e.g., dual users of e-cigarettes and another tobacco product). This resulted in varying sample sizes throughout the current study, and may limit the generalizability of some findings to the populations included (e.g., only dual users). Fourth, I ran several separate regression analyses in the current study due to large amounts of missing data and use of listwise deletion for logistic regression analyses. The high number of analyses conducted increased the likelihood of making a type I error (i.e., reporting a false-positive result). Finally, given that all attempts to quit e-cigarettes were failed attempts, these findings may not generalize to successful quit attempts. Despite these limitations, the current study is the first to my knowledge to examine e-cigarette use and cessation behaviors in a nationally representative sample of adult e-cigarette users in the United States and to prospectively predict the likelihood of making e-cigarette quit attempts based on individual and e-cigarette use characteristics. The current study extends prior work by using a large, nationally representative US adult sample and highlights that over 25% of e-cigarette users reported attempts to quit e-cigarettes, that 85% of adults making attempts to quit e-cigarettes completely report using common cessation strategies including counseling and FDA-approved medications, and by identifying factors such as interest in quitting vaping and e-cigarette dependence, which may prospectively predict attempts to quit e-cigarettes.

The current study highlights the need for continued research on e-cigarette

cessation, including a detailed, fine-grained analysis of patterns of use and cessation-related behaviors. These studies would aid in the tailoring of interventions for e-cigarette cessation, which may require different treatment methods than those used for combustible cigarettes. Further, studies should begin to examine the efficacy of existing cessation interventions, such as nicotine replacement or psychosocial interventions, among e-cigarette users.

Appendix A

Table 1

Baseline Sample Demographic Characteristics at Wave 2.

Demographics	Unweighted Frequency	Weighted Population Estimate (%)	95% Confidence Interval for Population Estimate
Age^a			
18 to 24 years old	537	24.1	[21.9, 26.4]
25 to 34 years old	374	27.2	[24.9, 29.7]
35 to 44 years old	250	17.8	[15.8, 20.1]
45 to 54 years old	205	14.5	[12.6, 16.7]
55 to 64 years old	153	11.4	[9.6, 13.5]
65 to 74 years old	46	4.4	[3.0, 6.3]
75 years old or older	7	0.6	[0.3, 1.2]
Sex^b			
Male	830	55.4	[52.2, 58.6]
Female	742	44.6	[41.4, 47.8]
Race^c			
White alone	1237	81.9	[79.4, 84.2]
Black alone	134	8.8	[7.1, 11.0]
Other	182	9.3	[7.7, 11.1]
Ethnicity^d			
Hispanic	210	10.6	[9.1, 12.2]
Not Hispanic	1353	89.4	[87.8, 90.9]
Household Income^e			
Less than \$50k	485	35.3	[32.3, 38.4]
More than \$50k	1028	64.7	[61.6, 67.7]

^an=1572; ^bn=1572; ^cn=1553; ^dn=1553; ^en=1513

Appendix B

Table 2

E-cigarette, Mental Health, and Substance Use Characteristics at Wave 2.

Variable	Sample Size	Sample Mean or Percent of Sample	95% Confidence Interval
E-cigarette Use Characteristics			
E-cigarette Dependence (on 1-5 scale)*	801	1.9	[1.8, 2.0]
Days of E-cigarette Use (in past 30 days)	1021	19.9	[19.1, 20.7]
Tobacco e-liquid Flavor Use	961		
Yes		22.3%	[19.2, 25.7]
No		77.7%	[74.3, 80.8]
E-cigarette Quitting Interest (on scale of 1-10)*	641	3.6	[3.4, 3.9]
Confidence in Ability to Quit E-cigarettes (on scale of 1-4)*	98	3.4	[3.3, 3.6]
Number of Reasons for Using E-cigarettes (out of 13)*	1132	7.6	[7.4, 7.7]
Mental Health Characteristics			
Number of Internalizing Disorder Symptoms (out of 4 symptoms)	1567	1.9	[1.8, 2.0]
Number of Externalizing Disorder Symptoms (out of 5 symptoms)	1568	1.2	[1.1, 1.2]
Non-Tobacco Substance Use Characteristics			
Problematic Use of At Least One Substance	533		
Yes		44.2%	[39.0, 49.7]
No		53.7%	[50.3, 61.0]
Days of Cigarette Smoking (in past 30 days)*	968	24.4	[23.7, 25.1]

* Data only available from dual/poly tobacco users by design of the PATH study.

Note: Higher numbers on Likert scales above denote more of the relevant construct.

Appendix C

Table 3

Formal and informal e-cigarette cessation strategies endorsed by e-cigarette users at Wave 3.

Cessation Strategy Endorsed	Unweighted Frequency	Weighted Population Estimate (%)	95% Confidence Interval for Population Estimate
Support from family and friends ^a	44	26.7	[19.8, 35.8]
Counseling/self-help ^b	18	12.2	[7.1, 20.2]
Use of another tobacco product ^c	35	21.5	[15.1, 29.6]
Nicotine replacement therapy ^d	31	75.4	[58.3, 87.0]
FDA-approved prescription cessation medication ^e	18	68.2	[48.9, 82.7]
No cessation strategies used ^f	24	15.2	[10.1, 22.1]

^an=170; ^bn=170; ^cn=168; ^dn=41; ^en=26; ^fn=170

^b This response option included use of counseling, self-help, books, pamphlets, videos, tobacco clinics, classes, support groups, or web-based programming.

Note: Only participants who endorsed use of nicotine replacement or other FDA-approved prescription cessation medication within the past year responded to survey questions about use of medications for e-cigarette cessation.

Appendix D

Table 4

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and interest in quitting e-cigarettes among dual/poly tobacco users.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Interest in Quitting E-cigarettes	1.2	[1.2–1.3]	<.001
Race			
Black alone	1.7	[0.8–3.9]	.19
Other	0.9	[0.5–1.7]	.77
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.9	[0.4–2.0]	.82
Hispanic	[Reference]		
Sex			
Female	0.6	[0.4–0.9]	.02
Male	[Reference]		

Note: Sample size = 632

Appendix E

Table 5

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and perceived confidence in quitting e-cigarettes among dual/poly tobacco users.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Confidence in quitting	0.7	[0.2–1.8]	.40
Race			
Black alone	1.4	[0.3–7.7]	.69
Other	1.7	[0.2–12.3]	.62
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.7	[0.1–5.4]	.73
Hispanic	[Reference]		
Sex			
Female	0.4	[0.1–1.2]	.11
Male	[Reference]		

Note: Sample size = 94

Appendix F

Table 6

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and number of reasons for e-cigarette use among dual/poly tobacco users.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Number of reasons for e-cigarette use	1.0	[0.9–1.1]	.95
Race			
Black alone	3.2	[1.8–5.6]	<.001
Other	0.9	[0.6–1.5]	.79
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.9	[0.5–1.6]	.66
Hispanic	[Reference]		
Sex			
Female	0.8	[0.5–1.1]	.22
Male	[Reference]		

Note: Sample size = 1086

Appendix G

Table 7

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and cigarette use frequency at Wave 2 among dual/poly tobacco users.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Cigarette use frequency	1.0	[0.9–1.0]	.10
Race			
Black alone	2.5	[1.4–4.5]	.002
Other	1.1	[0.6–2.0]	.85
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.9	[0.5–1.4]	.53
Hispanic	[Reference]		
Sex			
Female	0.7	[0.5–0.9]	.01
Male	[Reference]		

Note: Sample size = 940

Appendix H

Table 8

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-cigarette dependence among dual/poly tobacco users.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
E-cigarette Dependence	1.3	[1.1–1.6]	.01
Race			
Black alone	2.4	[1.2–4.7]	.01
Other	1.0	[0.6–1.9]	.90
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.8	[0.4–1.6]	.54
Hispanic	[Reference]		
Sex			
Female	0.7	[0.5–1.1]	.10
Male	[Reference]		

Note: Sample size = 775

Appendix I

Table 9

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and mental health symptoms and substance use.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Problematic Substance Use			
Yes	1.8	[1.1–2.8]	.01
No	[Reference]		
Internalizing Disorder Symptoms	0.9	[0.7–1.1]	.52
Externalizing Disorder Symptoms	1.2	[1.0–1.5]	.07
Sex			
Female	1.0	[0.6–1.6]	.96
Male	[Reference]		
Race			
Black alone	2.2	[0.9–5.5]	.09
Other	1.0	[0.4–2.4]	.98
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.6	[0.3–1.2]	.14
Hispanic	[Reference]		

Note: Sample size = 498

Appendix J

Table 10

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-liquid flavor use.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
Use of e-liquid flavors			
Tobacco e-liquid flavor	0.7	[0.2–2.1]	.48
Non-tobacco e-liquid flavor	[Reference]		
Race			
Black alone	3.1	[0.8–13.1]	.11
Other	1.6	[0.4–5.5]	.48
White alone	[Reference]		
Ethnicity			
Not Hispanic	0.7	[0.2–3.4]	.73
Hispanic	[Reference]		
Sex			
Female	1.0	[0.4–2.6]	.99
Male	[Reference]		

Note: Sample size = 177

Appendix K

Table 11

Association between likelihood of attempting to quit e-cigarettes in the year prior to Wave 3 and e-cigarette use frequency.

	Adjusted Odds Ratio	95% Confidence Interval	<i>P</i>
E-cigarette use frequency	1.0	[0.9–1.0]	.26
Race			
Black alone	3.1	[1.6–5.9]	<.001
Other	0.8	[0.5–1.5]	.47
White alone	[Reference]		
Ethnicity			
Not Hispanic	1.0	[0.5–1.9]	.95
Hispanic	[Reference]		
Sex			
Female	0.8	[0.6–1.1]	.19
Male	[Reference]		

Note: Sample size = 978

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Rosen, R. L., & Steinberg, M. L. (2019). Interest in Quitting E-Cigarettes among Adults in the United States. *Nicotine & Tobacco Research*. doi: 10.1093/ntr/ntz062.

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