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Electronic cigarette dependence and demand among pod-mod users as a function of smoking status

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Abstract

Electronic cigarette (e-cigarette) use continues to proliferate with fast-paced product evolution. Pod mod e-cigarettes emerged on the market in 2015 and have changed the tobacco landscape again. However, little is known regarding their addiction potential among users. The current study describes e-cigarette dependence and demand among pod-mod users as a function of smoking status (current smokers/dual users, former smokers, and never smokers). Participants were 593 young adult (M_{age} = 25.9 years) JUUL users recruited via Amazon's Mechanical Turk. Respondents were specifically recruited based on current use of pod-mods (but may also be using other e-cigarette devices) and smoking status (never, former, and current/dual users). Participants completed online measures assessing e-cigarette dependence and demand. Dual users of pod-mods and cigarettes displayed greater e-cigarette dependence compared to current pod-mod users with no history of cigarette smoking (p = .033). Similarly, dual users showed the greatest levels of e-cigarette demand compared to both former smokers and those without a history of smoking (*ps* < *.05*). Dual users displayed the greatest e-cigarette dependence and demand. Future research should directly assess potential mechanisms for this effect and continue to monitor e-cigarette dependence as the tobacco landscape changes with the emergence of new e-cigarette products and innovations.

Keywords

dependence; demand; electronic cigarettes; dual use

Introduction

Electronic (e-)cigarettes are battery-powered devices that deliver an inhaled aerosol that typically contains nicotine, flavorants, propylene glycol, and vegetable glycerin. A number of studies suggest that e-cigarettes are markedly less harmful than combustible cigarettes

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(Abrams et al., 2018; Farsalinos & Polosa, 2014; NASEM, 2018; Stephens, 2018), though they may not be completely harmless as other studies show varying levels of some toxicants (Canistro et al., 2017; Hecht et al., 2014; Kosmider et al., 2014). E-cigarettes are quickly evolving and changing the tobacco landscape. Early generation e-cigarettes (i.e., cig-a-like e-cigarettes) did not effectively deliver nicotine (Bullen et al., 2010; Eissenberg, 2010; Farsalinos et al., 2015) and, as a result, were unlikely to serve as effective substitutes for regular cigarettes. Population surveillance and market data (Bullen et al., 2010; Hitchman et al., 2015) revealed that these early devices quickly waned in popularity. Later generation e-cigarettes (i.e., tank and mod system e-cigarettes) more effectively deliver nicotine, achieving levels comparable to those of cigarettes (Wagener et al., 2017), particularly among established users. Greater efficiency of nicotine delivery increases the likelihood of product substitution, but it also increases liability for dependence.

Not all e-cigarette users have the same history of smoking status, as some have come to e-cigarettes after smoking combustible cigarettes (former smokers), some have started de novo (never smokers) and some are using both (current smokers; i.e., dual users). It is important to understand dependence and proxies of it (e.g., consumer demand) among users with such varied histories of smoking. Few studies have done so, and all of these are based on earlier devices that reflect a marketplace that is now dated. For example, one study showed dual users have lower levels of e-cigarette dependence compared to former smokers who switched to exclusive e-cigarette user (Etter & Eissenberg, 2015). Another suggests greater past cigarette dependence compared to current e-cigarette dependence among former smokers who switched to e-cigarettes (e.g., cig-a-like) and, similarly, greater cigarette dependence compared to e-cigarette dependence among current dual users (Farsalinos et al., 2014). In contrast, a recent prospective study showed that overall nicotine use and dependence increases as smokers transition to dual use (Martínez et al., 2019). These data suggest that smokers who completely switched to earlier generation e-cigarettes displayed greater dependence on cigarettes compared to e-cigarettes and that dual users of later generation e-cigarettes display increased nicotine dependence following transition from smoking to dual use. However, as the tobacco landscape evolves, and as e-cigarettes deliver nicotine more efficiently, it remains crucial to monitor and assess levels of nicotine dependence of their users, particularly among users of emerging products.

Pod-mod e-cigarettes have again altered the tobacco landscape. While reports of current (past month) use among adolescents and young adults vary widely (Ickes et al., 2019; McKelvey, Baiocchi, & Halpern-Felsher, 2018; Vallone et al., 2018; Willett et al., 2018), some indicate rates as high as 21% (McKelvey et al., 2018). Pod-mod devices are based on interchangeable, closed system pods that are prefilled with nicotinized e-liquid. They are generally small and sleek in appearance and are easily concealed by the user because of their dissimilarity to both combustible cigarettes and earlier generation e-cigarettes. JUUL (PAX Labs) entered the market in 2015 and quickly became the most popular pod-mod available (Herzog & Kanada, 2018). JUUL is a small, rechargeable e-cigarette, similar in appearance to a USB flash drive, that allows users to simply insert a pod into the base and inhale aerosolized, nicotine-containing e-liquid. Importantly, JUUL e-liquid contains 3–5% nicotine, much higher than earlier generation e-cigarettes. The company reports that each pod is equivalent to one pack of cigarettes or 200 puffs, and internal pharmacokinetic studies

indicate nicotine delivery comparable to that of a combustible cigarette (Brown & Xing, 2015; Eissenberg, 2018). Increased delivery of nicotine increases addictive potential, even beyond other e-cigarettes on the market. Moreover, whereas most other e-cigarettes use freebase nicotine, JUUL utilizes nicotine salts which both increases its bioavailability and decreases taste aversion (Chen, 1976; Pankow, 2001), thus increasing palatability among naïve users. Some studies suggest that just over a third of users believe that JUUL pods contains nicotine (Willett et al., 2018), indicating that unaware users are vulnerable to development of nicotine addiction.

Existing research has investigated nicotine dependence among users of earlier generation e-cigarettes as a function of cigarette use status; however, these studies are not reflective of users of the most current and prominent products on the market. The current study begins to fill this gap by describing e-cigarette dependence and demand among young adults pod mod users who report never, current, or former smoking. Current pod mod (i.e., JUUL) users between 18–30 years old were recruited given pod mods' prominence in the current market, particularly among young users. The current study assessed dependence and demand among the aforementioned use groups. Given research suggesting higher levels of dependence among former smokers that switch to e-cigarettes (Etter & Eissenberg, 2015), it was hypothesized that this pattern would hold true among pod mod users.

Methods

Sample

Participants were recruited for an anonymous, online cross-sectional survey via Amazon's Mechanical Turk (MTurk) from January to March 2019. Eligibility was restricted to young adults, aged 18–30 years, who lived in the US. Both JUUL users and non-users were recruited into the survey, but the latter group was dropped for the current analysis, focusing on current users (i.e., JUUL user at least 5 times per month for the past 3 months) only. We restricted our recruitment to be JUUL users in particular, but recognize that many of these individuals also used other e-cig devices (see below). Participants were enrolled across three use groups of combustible smoking: never, former, and current. Never smokers were those that denied smoking in the past 3 months and smoked <100 cigarettes in their lifetime. Former smokers denied smoking in the past 3 months and reported smoking at least 100 cigarettes in their lifetime. Current smokers reported smoking cigarettes at least 5 times per month for the past 3 months and smoking at least 100 cigarettes in their lifetime. Thus, three groups of cigarette smokers/pod mod users were recruited: 1) never smoker/current JUUL user (never smokers), 2) former smoker/current JUUL user (former smokers), and 3) current smoker/current JUUL user (dual users). Participants were unable to enroll in the study if they had previously completed the study or if they were unwilling or unable to provide informed consent.

Of 698 participants who were eligible and completed all procedures, 105 were removed due to endorsement of random responding and/or inaccurate responding to validity questions (see below). Outlier responses to individual items (e.g., willingness to spend $7,500 for a day of JUUL use) were removed but the individual was retained, leaving 593 survey

respondents. Of those, 39.1% (n = 232) were dual users, 31.5% (n = 187) were former smokers, and 29.3% (n = 174) were never smokers.

Potential participants self-selected into the survey from a list of studies and tasks on MTurk. Participants completed informed consent prior to screening and survey completion, and were compensated $1.75 for survey completion. Study procedures were approved by the university's Institutional Review Board.

Measures

Participant characteristics.—Participants completed measures assessing their age, sex, ethnicity, and level of education. Due to error in survey programming at the outset of the study, 9 participants are missing demographic information.

E-cigarette use.—Use of e-cigarettes, including cig-a-like, tank, mod, and JUUL e-cigarettes was assessed by items which presented a picture of the device and asked participants to identify their current use patterns. Response options included "daily or almost daily", "less than daily but at least weekly", "less than weekly but at least monthly", "less than monthly but at least yearly", and "not at all". To assess JUUL use patterns, respondents were provided a graphic of a JUUL e-cigarette and were asked only to answer questions in regards to JUUL use. They were provided a definition of a "session" which stated, "Throughout this survey, we will refer to vaping sessions. For the purposes of this study, a vaping session starts from your first puff and ends with your last puff before you take a break to do something else. A session can last any length of time and involve any number of puffs, depending on the person." Items assessed number of lifetime JUUL sessions and past 30 days use (i.e., number of days using JUUL out of the past 30 days). Participants further reported their age of first use and age of first regular (i.e., weekly for at least a month) JUUL use.

E-cigarette dependence.—Participants completed the Penn State Electronic Cigarette Dependence Index (Foulds et al., 2014), a 10-item measure of e-cigarette dependence. Items assess heaviness of use, time to first use, cravings/urges, nighttime use, and withdrawal (i.e., irritability, nervousness, difficulties abstaining). A total score is calculated by adding all items, yielding a possible range of 0–20, with higher score indicating greater dependence. E-cigarette dependence was measured generally (for e-cigarettes) rather than on a device-specific (e.g., JUUL vs. Other) due to anticipated difficulty differentiating between dependence on specific e-cigarette devices; see below for sensitivity analyses that address this.

E-cigarette demand.—Participants completed an e-cigarette adapted brief Cigarette Purchase Task (Jacobs & Bickel, 1999) consisting of three items. These items were adapted from the full E-cigarette Purchase Task (eCPT; Cassidy et al., 2017) and a 3-item measure of alcohol demand (Owens, Murphy, & MacKillop, 2015). The brief eCPT was modified to assess JUUL e-cigarette demand: (1) "If JUUL were free, how many times would you use JUUL in a single day? (Assume one "time" consists of 15 puffs or lasts around 10 minutes)", (2) What is the maximum total amount you would be willing to spend for a single

day's worth of JUULing (in dollars)?" and (3) "What is the maximum you would be willing to pay to use a JUUL for 10 minutes?" Unlike dependence which was asked about e-cigarettes in general (see above), demand was assessed specific to JUUL, under the belief that the concrete, face valid nature of the questions would facilitate ease of device-specific evaluation; i.e., that demand would be specific to device versus hypothetical for a class of devices.

Validity items.—Participants completed embedded validity questions throughout the survey and two face valid validity questions at the end of the survey. Participants were informed that their responses on the items would in no way affect their compensation. Face valid questions assessed random responding (e.g., "I answered items randomly without reading the items"; true/false). Seven validity items were embedded sporadically throughout the survey and stated, "Please select option [X]." Participants who responded to fewer than six out of seven questions correctly were excluded from analyses.

Data analysis

Descriptive statistics were analyzed for all scale scores and variables. Only participant age was statistically significantly different between user groups in bivariate analyses; however, we opted not to include age as a covariate since the overall difference between groups was negligible. A series of analyses of variance (ANOVAs) were conducted to compare use groups (dual users, former smokers, never smokers) in terms of e-cigarette dependence and demand. To isolate differences in dependence and demand among exclusive JUUL users who did not use other e-cigarettes ($N_{dual\ users} = 54$, $N_{former\ smokers} = 75$, $N_{never\ smokers} = 72$), sensitivity analyses were conducted. Exploratory ANOVAs were conducted with exclusive JUUL users after excluding individuals who self-reported current daily, weekly, or monthly use of other e-cigarettes; however, the current study was not sufficiently powered to detect effects among these subsamples. For all analyses, $p<.05$ was used to indicate statistical significance.

Results

Participant demographics.

Participants ($M_{age} = 25.9$ years, $SD = 3.1$) were mostly men (59.2%) and identified as White/Caucasian (76.6%), Black/African American (8.4%), and Asian (7.3%). Approximately 59% of participants had at least a college degree. See Table 1 for complete demographic information.

E-cigarette use.

In the overall sample, 37.3% of participants reported current daily use of e-cigarettes other than JUUL, 19.6% reported weekly use, 9.3% reported monthly use, 12.6% reported less than monthly use, and 21.2% denied current use of other e-cigarettes. Among all participants, 51.2% reported having over 100 JUUL sessions in their lifetime and participants reported using JUUL on 19.2 ($SD = 10.3$) out of the past 30 days. Reported age of first JUUL use was 22.5 years old ($SD = 4.4$) and reported age of regular use was 22.7 ($SD = 4.6$). See Table 1 for complete e-cigarette use information.

E-cigarette dependence.

Significant group differences in level of dependence emerged between groups (dual users vs. former smokers vs. never smokers); $F(2, 590) = 3.2$, $p = .043$. Pairwise comparisons showed that dual users displayed significantly greater e-cigarette dependence compared to never smokers ($p = .033$); pairwise comparisons between dual users and former smokers failed to reach statistical significance. See Table 2 for complete results by group. In the subsample of JUUL users who denied current, at least monthly other e-cigarette use (n=201), no significant group differences in level of dependence emerged between groups; however, analyses were underpowered to detect these effects; $F(2, 198) = 0.6$, $p = .555$.

E-cigarette demand.

Significant group differences emerged for the number of times participants would use JUUL in a day if it were free; $F(2, 585) = 6.5$, $p = .002$. Dual users ($p = .001$) and former smokers ($p = .024$) reported an intention to use a greater number of times compared to never smokers. Group difference emerged for the maximum amount participants were willing to spend for a single day's worth of JUUL; $F(2, 574) = 5.6$, $p = .004$. Dual users reported a willingness to spend a greater maximum total amount for a single day's worth of JUUL compared to former smokers ($p = .003$). Group differences emerged in terms of the maximum amount participants were willing to spend for a single day of JUUL use; $F(2, 575) = 9.4$, $p < .001$. Specifically, dual users reported a willingness to spend a greater amount than former smokers ($p < .001$). See Table 2 for complete results by group.

In the subsample of exclusive JUUL users, significant group differences emerged for the maximum amount participants were willing to spend for 10 minutes of JUUL use; $F(2, 196) = 5.8$, $p = .003$. Dual users ($p = .022$) and never smokers ($p = .006$) reported a willingness to spend a greater amount than former smokers. No significant group differences emerged for the number of times participants would use JUUL if it were free or maximum they would be willing to spend for a day's just of JUUL.

Discussion

The present study evaluates levels of e-cigarette dependence and demand among pod-mod users with varied histories of combustible cigarette smoking (never, former, current smokers/ dual users). Consistent with previous research on earlier generation e-cigarettes (Farsalinos et al., 2014; Foulds et al., 2014; Nardone et al., 2019), findings suggest that dual users of e-cigarettes and cigarettes displayed greater e-cigarette dependence compared to never smokers. Similarly, dual users reported the greatest overall demand for e-cigarettes.

There are several mechanisms by which dual use could translate into increased dependence. One such mechanism is the potential exposure to increased levels of nicotine, which could be particularly salient as newer devices offer increased nicotine delivery. Dual users may be exposed to higher total levels of nicotine due to greater use (e.g., greater number of puffs per day, more frequent puffs) or more efficient nicotine extraction and delivery (e.g., longer puff duration, greater flow rate, increase puff volume and duration resulting in improved nicotine extraction) across products compared to exclusive e-cigarette use. However, several studies

have shown that users titrate intake of nicotine across multiple products to approximate what they get with one (Dawkins et al., 2016; Farsalinos et al., 2017; Gable, 1993), which is consistent with other evidence that shows comparable cotinine levels between dual users and exclusive e-cigarette users (Piper et al., 2018). That being said, it is possible that with the proliferation of highly nicotinized e-liquid, such as that found in pod-mods like JUUL, dual users may be exposed to greater levels of nicotine compared to exclusive e-cigarette users. This remains an unanswered question as no research has investigated differences in nicotine and cotinine levels between these use groups in the context of highly nicotinized pod-mods.

Smokers who are prone to dependence may have more difficulty switching completely from cigarettes to e-cigarettes, making it more likely that individuals who are highly dependent will be dual users than former smokers. Alternatively, smokers who use e-cigarettes to quit smoking and are able to completely switch (i.e., former smokers) may be less dependent users, suggesting that dual users and former smokers who transition to exclusive e-cigarette use may represent distinct groups of tobacco users.

Differences in nicotine dependence may be driven primarily by reasons for and motivations to use cigarettes and e-cigarettes. Whether and how nicotine dependence correlates with reasons or motivation for using e-cigarettes is not clear, particularly with regard to newer devices, though such relationships (between reasons for use and dependence) have been suggested for combustible cigarettes (Berlin et al., 2003). Future research should assess these potential mechanisms by (1) objectively measuring and comparing nicotine/cotinine levels and smoking topography between dual users and former smokers who transition to e-cigarette use, (2) prospectively monitoring dependence among smokers as they attempt to transition to exclusive e-cigarettes use, (3) prospectively assessing smoking history prior to e-cigarette initiation and motivations and reasons for e-cigarette initiation.

Use of e-cigarettes, dependence, and demand among never smokers deserves special attention. In the current study, these users showed comparable levels of dependence to former smokers. Serious concerns have been raised by regulatory bodies, the scientific community, and the public regarding pod-mod and other e-cigarette use among young adults otherwise naïve to tobacco/nicotine (Barrington-Trimis & Leventhal, 2018). Some (Barrington-Trimis et al., 2018; Leventhal et al., 2016; Leventhal et al., 2015) but not all studies (Meier et al., 2015) suggest that e-cigarette use among smoking-naïve young adults could lead to transitions toward more harmful combustible tobacco products. To the extent that these transition trajectories are further supported, regulatory bodies will need to move swiftly to prevent this exposure to additional harm.

While an important first step, the study is not without limitations. This convenience sample was recruited from MTurk and may not generalize to other e-cigarette users and smokers. However, data suggest that MTurk users mimic more generalizable samples in their tobacco use behaviors (Kraemer et al., 2017). Additionally, the sample was comprised of majority white and male participants. It is unclear if this demographic make-up is due to the survey method or reflective of pod-mod users in the US. While recent studies suggest pod-mod users are more likely to be male, younger, and report higher socioeconomic status (Case, Hinds, Creamer, Loukas, & Perry, 2020), the current study is limited in the ability to make

conclusions about the correlation between user demographics and use status. Second, while participants in the overall sample were JUUL users, many were users of other e-cigarettes, making drawing conclusions regarding JUUL-specific dependence impossible. Sensitivity analyses aimed to understand JUUL-specific dependence among a subsample of exclusive JUUL users; however, the current study was underpowered to detect these effects. This also shows that loyalty to one product alone may be soft. Third, the measure of dependence utilized in the current study focuses primarily on amount and frequency of product use, which ignores other aspects of dependence (e.g., stimulus control, behavioral rituals, latency to withdrawal-related discomfort) that are included in common measures of cigarette dependence (DiFranza, Ursprung, & Biller, 2012; Glover et al., 2005; Piper et al., 2004; Shiffman, Waters, & Hickcox, 2004).

The current research begins to answer important questions regarding levels of e-cigarette dependence and demand among pod-mod users with varied smoking histories. Findings from this study provide evidence of greater levels of e-cigarette dependence and demand among dual users of e-cigarettes and cigarettes compared to single product users. Future research should continue to monitor dependence as the tobacco landscape changes with the emergence of new e-cigarettes products and device innovations with the aim of preventing transition to more harmful, combustible products.

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Table 1.

Participant characteristics and product use patterns by use group - *n(%)/M(SD)*

Characteristic	Dual users	Former smokers	Never smokers	p-value
Participants	232 (39.1)	187 (31.5)	174 (29.3)	---
Age (years)	25.7 (2.9)	26.5 (3.0)	25.4 (3.3)	**.002**
Sex				.703
Male	131 (58.7)	117 (62.6)	103 (59.2)	
Female	92 (41.3)	70 (37.4)	71 (40.8)	
Ethnicity				.056
White	177 (79.4)	140 (74.9)	137 (78.7)	
Black	23 (10.3)	11 (5.9)	16 (9.2)	
Asian	10 (4.5)	23 (12.3)	10 (5.7)	
Other	13 (5.8)	13 (7.0)	11 (6.3)	
Education				.237
Some HS	5 (2.2)	1 (0.5)	2 (1.1)	
12th/GED	28 (12.6)	22 (11.8)	19 (10.9)	
1–3y college	69 (30.9)	48 (25.7)	38 (21.8)	
≥ College	121 (54.3)	116 (62.0)	115 (66.1)	
Current non-JUUL e-cigarette use				**<.001**
Daily or almost daily	92 (39.7)	79 (42.2)	50 (28.7)	
Less than daily but at least weekly	55 (23.7)	25 (13.4)	36 (20.7)	
Less than weekly but at least monthly	31 (13.4)	8 (4.3)	16 (9.2)	
Less than monthly but at least yearly	36 (15.5)	16 (8.6)	23 (13.2)	
Not at all	18 (7.8)	59 (31.6)	49 (28.2)	
Number of JUUL lifetime sessions				**.001**
1 session	2 (0.9)	5 (2.7)	7 (4.0)	
2–4 sessions	16 (6.9)	5 (2.7)	19 (10.9)	
5–10 sessions	26 (11.2)	12 (6.4)	24 (13.8)	
11–20 sessions	18 (7.8)	9 (4.8)	15 (8.6)	
21–50 sessions	35 (15.1)	19 (10.2)	17 (9.8)	
51–100 sessions	31 (13.4)	20 (10.7)	21 (12.1)	

Characteristic	Dual users	Former smokers	Never smokers	p-value
100+ sessions	104 (44.8)	117 (62.6)	71 (40.8)	
Days using JUUL out of the past 30	17.6 (9.8)	21.8 (10.2)	17.2 (10.4)	**<.001**
Age of first JUUL use (years old)	22.2 (3.8)	24.1 (3.6)	20.96 (4.4)	**<.001**
Age of first regular JUUL use (years old)	22.5 (3.8)	24.5 (3.7)	21.1 (4.3)	**<.001**

Note. ANOVAs and Chi-Squared tests were used to test for significant difference between use groups. Bolded values indicate significant omnibus tests.

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Table 2.

Dependence and demand by use group – M(SD)

Outcome	Dual users	Former smoker	Never smoker	F	*p*
Penn State E-cigarette Dependence	8.0 (4.1)[a]	7.6 (4.0)[a,b]	7.0 (4.2)[b]	3.2	**.043**
Times use if free	9.6 (10.8)[a]	8.9 (8.4)[a]	6.4 (6.2)[b]	6.5	**.002**
Max. for day of use (dollars)	11.7 (12.3)[a]	7.9 (8.3)[b]	10.6 (13.2)[a,b]	5.6	**.004**
Max. spent for 10 minutes of use (dollars)	5.7 (8.0)[a]	2.9 (4.9)[b]	4.3 (5.7)[a,b]	9.4	**<.001**

Note. Non-matching superscripts within each row indicate significant pairwise comparisons.