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Electronic cigarette use among adult smokers: longitudinal associations with smoking and trait impulsivity

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ABSTRACT

Objective: The present exploratory study uses a longitudinal design to assess the associations between electronic cigarette (e-cigarette) use and cigarette smoking, motivation to quit and trait impulsivity among adult smokers.

Methods: One hundred and sixteen cigarette smokers only and ninety-one dual users (smoke cigarettes and use e-cigarettes) were recruited (mean age [standard deviation] = 25.11[6.94], male = 48.3%). Participants were recruited online and 121 were followed-up at 3 months. Participants completed online questionnaires regarding socio-demographics, smoking/e-cigarette use characteristics and trait impulsivity at baseline, and they self-reported their smoking status at 3-month follow-up.

Results: The use of e-cigarettes in cigarette smokers was associated with a higher rate of stopping cigarette smoking at follow-up, relative to smokers who did not use e-cigarettes ($\chi^2[1] = 11.03, p < 0.01$). Multivariate logistic regressions controlling for age and gender showed a significant association between motivation to quit and stopping cigarette smoking at follow-up (odds ratio = 2.11, 99% Confidence Interval = 1.12–3.97, $p < 0.01$). There was no link between trait impulsivity and stopping cigarette smoking.

Conclusions: The data suggest that e-cigarettes may increase rates of quitting cigarette smoking.

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E-cigarette; cigarettes;
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Introduction


Stopping cigarette smoking is associated with large health benefits, though there are still more than a billion people around the world who smoke (World Health Organization (WHO), 2019). Most smokers want to quit; however, cigarette smoking is an addictive behavior, and many find it hard to remain abstinent in the long term (Hajek et al., 2013). It has been shown that approximately 70% of smokers who try to quit without support relapse within the first month of abstinence and fewer than 7% remain smoke-free long term (>1 year; Centers for Disease Control and Prevention (CDC), 2017; Hughes et al., 2004).

Evidence-based recommendations suggest that behavioral support and nicotine replacement therapy (NRT) products increase the chances of smoking abstinence, but even with this additional support long-term quit rates remain low (Cahill et al., 2016; Hughes et al., 2014). The limited success of such treatments can be attributed to the low speed of nicotine delivery, and to not adequately addressing the sensory and behavioral aspects of smoking (Wadgave & Nagesh, 2016), though other factors (e.g., social/environmental barriers) may also play a role. In contrast, electronic cigarettes (e-cigarettes), handheld electronic vaping devices which produce an aerosol by heating an e-liquid, have been designed to mimic cigarettes

in nicotine delivery, sensations, and behavioral rituals (Knight-West & Bullen, 2016). E-cigarette use may help smokers quit by offering a way to overcome some of the limitations of other NRT products. Indeed, examination of reasons for e-cigarette use showed that most smokers endorsed reasons related to quitting and reduction in health risks (Kale et al., 2020). However, evidence on the efficacy of e-cigarettes as smoking cessation aids remains limited and with discrepancies in the results reported. For example, findings from longitudinal studies suggest that only intensive daily e-cigarette use is associated with higher rates of quit attempts and smoking abstinence (Biener & Hargraves, 2015; Brose et al., 2015). In addition, systematic reviews of e-cigarettes and smoking cessation found limited evidence for any effect of e-cigarettes on smoking cessation and quit attempts (El Dib et al., 2017), or even reduced chances of quitting (Kalkhoran & Glantz, 2016). However, a recent systematic review of randomized controlled trials concluded that e-cigarettes with nicotine increase quit rates (Hartmann-Boyce et al., 2021).

These discrepancies in results may relate to how e-cigarette use is measured and differences in how e-cigarettes are used in experimental study settings versus in real world. Additionally, many studies have failed to account for important factors related to e-cigarette usage (i.e.,

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e-cigarette device, fluid), and to consider the characteristics of users (i.e., quitting history, motivation to quit, personality, e-cigarette use intensity and frequency, e.g., Biener & Hargraves, 2015; Brose et al., 2015; Zhu et al., 2017). Moreover, to the best of our knowledge, none of the existing studies examine whether impulsivity-related personality traits predict quitting smoking among e-cigarette users. Individual differences in trait impulsivity are increasingly recognized as a significant determinant of smoking cessation outcomes. It has been suggested that smokers with higher levels of trait impulsivity have greater difficulty quitting smoking than their less impulsive peers (Celma-Merola et al., 2017; Doran et al., 2004; Littlewood et al., 2017). Therefore, it seems likely that trait impulsivity may have a role in quitting among e-cigarette users.

The primary aim of the present study is to investigate whether e-cigarette use is associated with stopping cigarette smoking. Secondary aims include: (a) to assess whether stopping cigarette smoking is associated with trait impulsivity, cigarette dependence, motivation to quit and previous quit attempts; (b) to explore the reasons and characteristics associated with e-cigarette use among adult smokers.

Materials and methods

Participants and procedure

Two hundred and seven individuals were recruited, and 121 of these were successfully followed-up after 3 months. Participants were recruited using online message forums, through e-mails sent via Goldsmiths, University of London, and through Prolific (www.prolific.co). Participants recruited through Prolific ($n = 67$, 43.8%) were older, more often dual users and were paid £1.70 for completing each of the baseline and the follow-up questionnaires. All other participants received no compensation. Participants' inclusion criteria were being ≥ 18 years old, either a cigarette smoker only (reporting current cigarette smoking and not having used an e-cigarette in the last month) or dual user (reporting current cigarette smoking and e-cigarette use in the last month; for the questions used to classify participants to each group please see [supplementary materials](#)), able to read and understand English and having an active e-mail address account. Initial recruitment took place between May–September 2018 (153 participants; cohort 1) and January–July 2020 (54 participants; cohort 2), and no differences were observed between the two cohorts; these numbers were the maximum sample that was able to be recruited in the timeframe and resources available for the study. The sample size for this study, therefore, was not based on an attempt to achieve specific power to detect a particular effect size.

Informed consent and measures were completed online in Qualtrics. Three months after completing baseline measures, participants were emailed a link to complete a follow-up questionnaire, with up to three reminders sent. The study was approved by Goldsmiths, University of London, Psychology Department Ethics Committee.

Measures

All measures, along with answer options, can be found in the [supplementary material](#). At baseline, participants reported age, gender, employment status, and ethnicity. Cigarette dependence was measured with the Fagerström (2012) test for cigarette dependence. We assessed age when participants started smoking and previous quit attempts of ≥ 1 month, along with motivation and intention to quit smoking in the next 3 months via questions used in previous research (Gilbert et al., 2017).

Dual users reported e-cigarette use (number of days using e-cigarettes in last month, average number of vapes and milliliters of e-liquid used per day, type of cartridge used; Bold et al., 2018), their main reasons for using e-cigarettes (Table 6; CDC, 2016; Farsalinos et al., 2014; Kale et al., 2020), and to what extent they use their e-cigarette to help them quit smoking.

Impulsivity was measured with the UPPS-P Impulsive Behaviour Scale (Cyders et al., 2007; Whiteside & Lynam, 2001), which assesses five dimensions of trait impulsivity: negative urgency, positive urgency, lack of premeditation, lack of perseverance, and sensation seeking. The mean score for each dimension was calculated, giving a score between 1 and 4 (4 = highest trait expression). Cronbach's alpha values in the present sample were lack of premeditation = 0.85, lack of perseverance = 0.84, sensation seeking = 0.86, negative urgency = 0.88, positive urgency = 0.96. Correlations between the UPPS-P subscales ranged between 0.04 and 0.66, with the highest correlation between negative urgency and positive urgency, suggesting that the subscales index largely distinct components of impulsivity.

At follow-up, participants were asked how long it was since they smoked their last cigarette, and if they have ever used e-cigarettes, how long it was since they used them (questions adapted from Gilbert et al., 2017). Participants were classified as successful quitters if they had not smoked cigarettes or used e-cigarettes in the last month, cigarette smokers if they smoked only cigarettes in the last month, dual users if they both smoked cigarettes and used e-cigarettes in the last month, and e-cigarette users if they only used e-cigarettes in the last month. We also assessed number of attempts participants made to stop smoking in the last 3 months, and if participants had remained abstinent for 7 consecutive days in the last 3 months.

Statistical analysis

Data were analyzed using IBM SPSS V23. All baseline variables had fewer than 5% missing values. Missing trait scores at baseline were low (<5%), missing at random, and they were imputed using expectation maximization. Results were similar when we removed all cases with missing data. Owing to the large number of analyses conducted, an alpha level of $p = 0.01$ was used for significance testing to reduce the likelihood of Type I errors, and we reported 99% confidence intervals (CI).

Independent sample t-tests and chi-squared tests were conducted to assess differences in baseline characteristics between participants that completed the follow-up and those that did not and to assess differences in baseline characteristics between cigarette smokers only and dual users at baseline. Chi-squared tests were also conducted to assess differences in smoking status and

quit attempts between baseline cigarette smokers only and dual users at follow-up.

Logistic regression analyses, controlling for age and gender, were used to examine separately whether e-cigarette use, motivation to quit, cigarette dependence, previous quit attempts, and impulsivity-related traits, were each significant predictors of stopping cigarette smoking at follow-up. In addition, logistic regression analyses, controlling for age and gender, were conducted for the baseline dual users to examine if intensity of e-cigarette use, reasons for e-cigarette use and motivation to quit at baseline each predicted stopping cigarette smoking at follow-up.

Results

Attrition

Paid participants recruited through Prolific had a higher retention rate than other participants ($p < 0.01$). No other significant differences were found (Table S1).

Descriptive statistics

Participants' sociodemographic characteristics are presented in Table 1. Almost half were cigarette smokers only at baseline, their mean age was 25.11 years old (standard deviation [SD] = 6.94), and almost half were males. Most of the participants were white and were university students. Cigarette smokers only did not differ significantly from dual users across any demographic characteristics.

Most of the participants started smoking after the age of 16 years old and were daily smokers with low levels of cigarette dependence; almost half indicated that they had quit in the past. Compared to cigarette smokers only, dual users showed higher intention and motivation to quit in the next 3 months though the differences were not significant (Table 2).

A comparison of the two groups across the trait impulsivity facets (Supplementary Information Table S2) showed no significant differences.

Table 1. Demographic characteristics.

Variable	Total n = 207		Cigarette Smokers n = 116 (56.0%)		Dual users n = 91 (44.0%)		t-test (dfs)	p-value
	Mean	SD	Mean	SD	Mean	SD		
Age	25.11	6.94	25.64	7.21	24.43	6.56	1.246 (205)	0.148
	No.	%	No.	%	No.	%	Chi² (df)	
Gender								
Male	100	48.3	55	47.4	45	49.5	0.09 (1)	0.771
Female	107	51.7	61	52.6	46	50.5		
Ethnicity								
White	178	86.0	101	87.1	77	84.6	0.26 (1)	0.614
Other	29	14.0	15	12.9	14	15.4		
Occupation								
Student	140	67.6	79	68.1	61	67.0	0.13 (2)	0.938
Employed	59	28.5	33	28.4	26	28.6		
Unemployed	8	3.9	4	3.5	4	4.4		

Note Dual users=both smoke cigarettes and use an e-cigarette, SD=Standard Deviation, df=degrees of freedom, n=number of participants, p=alpha value.

Table 2. Baseline tobacco use, cessation history, and intention to quit.

Variable	Cigarette Smokers n = 116 (56.0%)		Dual users n = 91 (44.0%)		Chi ² (df)	p-value
	No.	%	No.	%		
Days per month of cigarette smoking						
1–9 days	16	13.8	10	11.0	3.61 (3)	0.607
10–19 days	19	16.4	11	12.1		
20–29 days	26	22.4	19	20.9		
30 days	55	47.4	51	56.0		
Numbers of cigarette smoked per day						
≤10	73	62.9	49	53.8	13.535 (3)	0.004
11–20	30	25.9	32	35.2		
21–30	4	3.4	10	11		
>30	9	7.8	0	0		
Age started smoking						
<14	11	9.5	6	6.6	0.993 (2)	0.609
14–16	42	36.2	38	41.8		
>16	63	54.3	47	51.6		
Quit for longer than a month						
no	63	54.3	53	58.2	0.32 (1)	0.572
yes	53	45.7	38	41.8		
Intention to quit smoking in the next 3 months						
no	79	68.1	46	50.5	6.57 (1)	0.01
yes	37	31.9	45	49.5		
	Mean	SD	Mean	SD	t-test (dfs)	p-value
Cigarette dependence	2.99	2.94	3.56	2.50	–1.47(203)	0.143
Mean score “How much do you want to quit?” (scale1–5)	2.86	1.33	3.32	1.28	–2.49 (205)	0.014

Note Dual users=both smoke cigarettes and use an e-cigarette, SD=Standard Deviation, df=degrees of freedom, n=number of participants, p=alpha value.

Most dual users reported using their e-cigarette 1–4 times per day, they consumed on average 5.61 milliliters of e-liquid per day (SD = 6.56), and they mostly used a nicotine-containing cartridge. Their main reason given for e-cigarette use was that e-cigarettes are less harmful than cigarettes, while the second most important reason given was that e-cigarettes can be used indoors (Table 3).

Dual users who intended to quit smoking more frequently endorsed the reason “aid to stop smoking” than those who did not intend to quit ($\chi^2[1] = 15.28, p < 0.001$). Their mean score on the extent that they use e-cigarettes to help them quit smoking was 3.55 (SD = 1.11) compared to 2.36 (SD = 0.98) for dual users who did not intend to quit ($t[87] = 5.37, p < 0.001$). No other significant differences were found.

Smoking status at follow-up

Of the 60 baseline cigarette smokers who completed the follow-up, 4 had not smoked cigarettes for at least 1 month at follow-up, while of the 61 dual users, 16 indicated had not smoked cigarettes for at least 1 month. This difference was significant ($\chi^2[1] = 11.03, p < 0.01$). More dual users had quit

smoking for 7 consecutive days at the follow-up compared to cigarette smokers only ($\chi^2[1] = 7.19, p < 0.01$). No other significant difference was found (Table 4).

Baseline predictors of stopping cigarette smoking at follow-up

E-cigarette use and motivation to quit increased the odds of stopping cigarette smoking for at least 1 month (OR = 5.16, 99% CI = 1.09–24.41, $p < 0.01$; OR = 2.11, 99% CI = 1.12–3.97, $p < 0.01$ respectively). Cigarette dependence and previous quit attempts did not predict stopping cigarette smoking for at least 1 month (OR = 1.06, 99% CI = 0.83–1.53, $p = \text{non-significant}$ (NS); OR = 1.29, 99% CI = 0.69–2.41, $p = \text{NS}$ respectively). No significant results were found when all variables were entered in the same model. Examining the association between each impulsivity-related trait and stopping smoking cigarettes for at least 1 month separately, no significant associations were observed (Table 5). Additionally, no significant associations were observed with stopping cigarette smoking for at least 1 month and any e-cigarette characteristics among baseline dual users (Table 6).

Table 3. Baseline e-cigarette use and reasons for use (dual users only).

Variable	Dual users = 91	
	No	%
Reason for e-cigarette use		
Perception that they are less harmful than cigarettes		
Yes	56	61.5
No	35	38.5
Can be used indoors		
Yes	52	57.1
No	39	42.9
Cheaper than tobacco products		
Yes	37	40.7
No	54	59.3
Novelty		
Yes	4	4.4
No	87	95.6
Aid to stop smoking		
Yes	50	54.9
No	41	45.1
Range of different flavors available		
Yes	34	37.4
No	57	62.6
E-cigarette use		
Days of vape/month		
6–9 days	24	26.4
10–19 days	20	22.0
20–29 days	14	15.4
All 30 days	33	36.3
Times of vape/day		
1–4	55	61.1
5–9	18	20.0
10–14	4	4.4
15–19	3	3.3
20–29	8	8.9
Cartridge		
Nicotine free	8	8.9
Nicotine containing	67	74.4
Both	15	16.7
	Mean	SD
use e-cigarette to quit cigarette smoking	2.94	1.20
millilitres e-liquid/day	5.61	6.56

Note Dual users=both smoke cigarettes and use an e-cigarette.

Table 4. Smoking status at follow-up.

	Cigarette Smokers (n = 60)		Dual users (n = 61)		Chi ² (df)	p-value
	No.	%	No.	%		
Stopping cigarette smoking for at least 1 month at T2						
Yes	4	6.7	16	26.2	11.03 (1)	0.004
No	56	93.3	45	73.8		
Smoking status at T2						
Successful quitters	3	5.0	4	6.6	62.98(3)	<0.001
Smokers	53	88.3	11	18.0		
Dual users	3	5.0	34	55.7		
E-cigarette users	1	1.7	12	19.7		
Any quit attempt the last 3 months at T2						
Yes	18	30.0	31	50.8	4.65 (1)	0.031
No	42	70.0	30	49.2		
Not smoking cigarettes for 7 days the last 3 months at T2						
Yes	12	20.0	26	42.6	7.19 (1)	0.007
No	48	80.0	35	57.4		

Note Dual users=both smoke cigarettes and use an e-cigarette, df=degrees of freedom, n=number of participants, p=alpha value.

Table 5. Association between impulsivity-related traits and stopping cigarette smoking at 3 months follow-up (logistic regression analyses for each impulsivity trait separately, controlling for age and gender).

	OR [99%CI]	p
Negative Urgency	0.75 [0.63–3.32]	0.529
Positive Urgency	0.75 [0.28–2.00]	0.456
Lack of Premeditation	0.85 [0.24–3.01]	0.733
Lack of Perseverance	1.45 [0.40–5.24]	0.457
Sensation Seeking	1.20 [0.42–3.44]	0.664

Note OR: odds ratio, CI: Confidence Intervals.

Discussion

The present study suggests that e-cigarette use is associated with an increased frequency of stopping cigarette smoking (not smoking cigarettes for at least 1 month at 3 months follow-up) among adult smokers. This finding is in line with some research that indicates e-cigarettes are a useful smoking cessation aid (i.e., Beard et al., 2016; Hartmann-Boyce et al., 2020). The results of the present study do differ, however, from some previous studies that found no association (i.e., Bullen et al., 2013), or even a negative correlation (Kalkhoran & Glantz, 2016), between e-cigarette use and smoking abstinence. E-cigarette devices have evolved a lot since they were first introduced to the market, and nowadays they provide increased control over vapor production and a greater concentration of nicotine than older devices, and most smokers

who successfully quit smoking report using more recently developed devices (Chen et al., 2016; Hitchman et al., 2015; R  ther et al., 2018). Additionally, the popularity of e-cigarette use grows constantly and more people, especially smokers, use them intensively (Action on Smoking and Health Ash., 2020). Intensive use has also been linked with smoking cessation (Biener & Hargraves, 2015; Hitchman et al., 2015). The present study found that 36.3% of dual users were using their e-cigarette every day, and this percentage is similar to the rates in other reports that found an association between e-cigarettes and smoking abstinence (Biener & Hargraves, 2015). In contrast, studies that found no association did not report intensity of e-cigarette use, or only reported “ever use” of e-cigarettes, and not current use.

The current study found no association between different levels of e-cigarette use and stopping cigarette smoking at follow-up. These null results might be attributed to the way frequency and intensity were measured. Quantifying frequency and intensity of e-cigarette use is difficult as e-cigarette users report that e-cigarette use typically occurs in short, frequent sessions that are difficult to count (Baweja et al., 2016). It should also be noted that the number of baseline dual users who stopped smoking cigarettes at follow-up was small, which means there is modest statistical power to detect any significant association between frequency and intensity of e-cigarette use and stopping cigarette smoking.

Table 6. Factors associated with stopping cigarette smoking at 3 months follow-up among dual users (univariate regression analyses controlling for age and gender).

	OR [99%CI]	p
Reason for e-cigarette use		
Perception that they are less harmful than cigarettes	1.038 [0.20–5.40]	0.954
Can be used indoors	1.349 [0.26–6.92]	0.637
Cheaper than tobacco products	1.610 [0.35–7.36]	0.419
Novelty	1.01 [0.04–24.99]	0.993
Aid to stop smoking	0.56 [0.12–2.55]	0.32
Range of different flavors available	1.057 [0.22–5.07]	0.927
E-cigarette use		
Days of vape/month	2.15 [0.98–4.70]	0.015
Times of vape/day	1.45 [0.84–2.51]	0.08
Cartridge	1.66 [0.28–9.79]	0.464
Use e-cigarette to quit	2.1 [1.00–4.41]	0.01
Mls e-liquid/day	0.97 [0.85–1.12]	0.615

Note OR: odds ratio, CI: Confidence Intervals.

Additionally, the present data suggest an association between stopping cigarette smoking and motivation to quit but not with cigarette dependence and past quit attempts. Previous research also indicates that motivation to quit is positively associated with quit attempts (Kale et al., 2015; Vangeli et al., 2011). However, it should be noted that dual users in the present study had higher motivation to quit at baseline than smokers, so we cannot clarify whether it was their e-cigarette use per se that contributed to their higher levels of quitting, or their differing levels of motivation, or both. Higher levels of cigarette dependence are also negatively associated with successful smoking cessation (Kale et al., 2015; Vangeli et al., 2011). The present sample had low levels of cigarette dependence, which may be a reason for not finding a significant association between cigarette dependence and not smoking cigarettes. Previous quit attempts have also been associated with future quit attempts, rather than smoking cessation (West et al., 2001; Zhou et al., 2009), whereas previous prolonged abstinence of 6 months or more has been found to positively predict smoking abstinence (Feng et al., 2011; Li et al., 2010). The present study assessed only whether participants had previously quit smoking for 1 month or longer.

Contrary to previous studies (i.e., Kahler et al., 2009; Littlewood et al., 2017), our results indicate that there is not a significant relationship between trait impulsivity and stopping cigarette smoking. This may be accounted for by the low numbers of participants who had stopped cigarette smoking at the follow-up, which may have limited the statistical power to find any association. Additionally, the discrepancy of the present results from previous research may be attributed to the study design, as most of the previous studies were clinical trials (Doran et al., 2004; Kahler et al., 2009; Littlewood et al., 2017).

Examining the reasons of e-cigarette use among dual users, we found that one of the most common reasons was as an aid for smoking cessation. Interest in quitting smoking is a common reason for e-cigarette use, possibly because e-cigarette use is promoted as an effective smoking cessation aid by e-cigarette advertisements in many countries (e.g., UK; de Andrade et al., 2013; Grana & Ling, 2014), even though such claims have not been accepted by some regulatory authorities (i.e., US Food and Drug Administration, 2016). E-cigarettes are also marketed as cigarette substitution in smoke-free environments (de Andrade et al., 2013; Grana & Ling, 2014) and could be used as such by highly nicotine-addicted smokers who have lower motivation and intention to quit smoking. In the present study, half of participants chose, as one of their reasons for e-cigarette use, that it can be used indoors.

A number of limitations should be noted in the present study. First, the sample was recruited online and had relatively low levels of cigarette dependence; thus, the results may be less relevant to other populations of cigarette smokers. The sample size was small, and our analyses were underpowered. Moreover, the 58.5% follow-up rate was relatively modest and higher in paid participants, which may have led to further selection biases and further loss of statistical power for tests involving the follow-up measures. The present study explored several participant characteristics; however, it did not assess characteristics of the

e-cigarette devices used. We may have also missed important factors associated with quitting smoking, such as the use of NRT or use of other combustible products, or the mental health status of respondents. It should also be noted that some participants were recruited during the COVID-19 pandemic, and they might have stopped smoking cigarettes because of the pandemic, though no difference was observed between participants recruited in different time points. A further limitation is that smoking status was exclusively self-reported and retrospective and stopping cigarette smoking at follow-up was not biochemically verified.

Nevertheless, the present study adds to current evidence that use of e-cigarettes may increase rates of smoking cessation (i.e., Adriaens et al., 2014; Biener & Hargraves, 2015). Future research is needed to follow up this initial exploratory study, using a larger sample, with greater follow-up retention, and assessment of e-cigarette device characteristics and other important factors associated with smoking abstinence. Such a study should provide greater insight into the relationship between e-cigarette use and smoking cessation among adults.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Availability of data

The dataset used and analyzed during the current study is available from the corresponding author (Dimitra Kale) on reasonable request.

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