

# Transitions in smoking and nicotine use from 2016 to 2017 among a UK cohort of adult smokers and ex-smokers

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## Abstract

**Introduction and Aims.** Smokers differ in how they smoke and how they stop smoking. Use of nicotine replacement therapy (NRT) and e-cigarettes further diversifies smokers. We aimed to identify and compare latent groups of past-year smokers and to describe longitudinal transitions between the identified groups. **Design and Methods.** Latent transition analysis of online UK past-year smokers' data ( $n = 2857$ ) collected in June 2016 and followed-up in October 2017. Latent groups were identified based on participants' smoking, e-cigarette use, NRT use, urges to smoke and last quit attempt. Sociodemographic and smoking characteristics between the groups were compared using Pearson's  $\chi^2$  test and Cramer's  $V$ . **Results.** Four latent groups of smokers (heavy smokers, light smokers, smokers using NRT, smokers using e-cigarettes) and two recently quit smokers (abstinent ex-smokers, ex-smokers using e-cigarettes) were identified. Nearly half the participants (48.9%) were heavy or light smokers who did not use alternative nicotine products and largely had not tried quitting smoking. Latent groups were relatively stable and transitions to quitting smoking were more probable in groups of smokers using alternative nicotine products. Smokers using NRT transitioned mostly to abstinent ex-smokers, and smokers using e-cigarettes to ex-smokers using e-cigarettes' groups (11.2% and 11.4%, respectively). The abstinent ex-smokers group grew the most at follow-up (+6.3%). **Discussion and Conclusions.** Nearly half of the participants continued smoking without having tried to reduce harm or quit. Of smokers who transitioned, the majority quit smoking and abstained from nicotine altogether. Use of alternative nicotine products alongside smoking was associated with higher probabilities of becoming an ex-smoker. [Simonavicius E, McNeill A, Brose LS. Transitions in smoking and nicotine use from 2016 to 2017 among a UK cohort of adult smokers and ex-smokers. *Drug Alcohol Rev* 2020;39:994–1005]

**Key words:** nicotine, smoking, e-cigarettes, nicotine replacement therapy, harm reduction.

## Introduction

Nicotine use in the United Kingdom (UK) is changing. In 2017, there were fewer smokers than ex-smokers in the UK (7.4 and 10.9 million, respectively), and at 15.1% adult smoking prevalence was at its lowest ever [1]. Between 2012 and 2018, the UK also experienced a surge in alternative nicotine use: the proportion of adult electronic cigarette (e-cigarette) users in the population increased from 1.7% to 6.2% and among smokers from 6.7% to 19.7% [2]. E-cigarettes allowed smokers to use nicotine in a less harmful way and provided an additional route to quitting smoking [3], but to date there is little evidence about transitions between smoking and alternative nicotine use.

Quitting smoking is erratic [4]. Two-thirds of smokers in the UK would like to quit [5], a third try to

quit every year, but only one in 20 actually stops smoking [6]. Relapse after stopping smoking is the norm: before stopping for a year, a smoker on average relapses 30 times [7]. Use of licensed cessation support, such as nicotine replacement therapies (NRT) or prescription medication (bupropion or varenicline), increases chances of success [8], but every year a substantial minority attempt to stop in the least efficient way—unassisted; in 2018, around 40% of the UK smokers tried to quit this way [9]. Those who use support mostly choose products available without prescription: e-cigarettes or over-the-counter NRT [10]. Of the two, e-cigarettes are more popular [6] and more effective in real-world and clinical studies [11,12]. Despite alternative nicotine products being less harmful than smoking [13,14], their potential to reduce tobacco-related harm remains untapped: only one in five smokers have used

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e-cigarettes more than once [2] and even fewer have ever used NRT [15].

Smokers have distinct smoking patterns, varying levels of dependence, different odds of stopping smoking and are using a wider range of alternative nicotine products given the diversification of these over the last few decades. Identifying different groups of smokers and how they change over time can help to see who benefits from alternative nicotine use and who requires a different approach to reduce harm or stop smoking. Latent Markov models are useful in analysing change trajectories between participants' subgroups within a heterogeneous sample and are commonly used in addiction research [16]. Latent transition analysis—a hidden Markov model—has been used to differentiate changes in adolescents' smoking patterns [17–21]; to the best of our knowledge, no similar research has investigated adult smokers' transitions between smoking, use of alternative nicotine products and abstinence over time.

Using a cohort of past-year smokers in the UK, our study aimed to: (i) identify and characterise latent groups and their prevalence among smokers and recent ex-smokers; and (ii) explore longitudinal transitions between the identified latent groups.

## Methods

### *Study design and sample*

Study data were from an online longitudinal cohort survey which has been run by the Nicotine Research Group at the Addictions Department, King's College London since 2012 [22,23]. We analysed the latest sample surveyed in 2016 and followed-up in 2017.

Participants were recruited from a UK panel managed by the market research company Ipsos MORI. Quota sampling was used to ensure representativeness: participants recruited in 2016 matched the UK population census estimates on age, gender and region. Additional details about the study sample and procedure are provided in the supplement.

Baseline study data were collected in May–June 2016 ( $n = 3431$ ) and followed-up in September–October 2017 ( $n = 1775$ ). We included participants who were past-year smokers in 2016. Ex-smokers for over a year ( $n = 425$ ) or exclusive pipe or cigars users ( $n = 149$ ) were excluded for not having key measures (*urges to smoke, last quit attempt*). The final sample included 2857 participants from 2016 and 1471 who were followed-up in 2017 (51.5% follow-up rate).

Ethical approval was granted by King's Psychiatry, Nursing and Midwifery Research Ethics Panel (LRS-16/17–4564).

### *Measures*

Study measures were taken from established population surveys: Smoking Toolkit Study [24] and International Tobacco Control Policy Evaluation Project [25].

To address the study aims, five categorical indicators were used for latent class and transition analyses (see Box 1). Smoking status (ex-smoker; non-daily; daily), vaping status (non-user; non-daily; daily) and use of nicotine replacement therapy (non-user; user) indicated participants' nicotine use patterns. Urges to smoke (no/slight to moderate; strong to extreme) scale (test–re-test reliability: 0.73, construct validity: 0.6–0.8) [26] indicated participants' nicotine dependence and last quit attempt (type of support used in the most recent serious quit attempt in the last 12 months: did not try; tried unassisted; tried assisted) was an indicator predicting the outcome of future cessation attempts [27].

For descriptive statistics, participants' sociodemographic and smoking measures from 2016 were used. Sociodemographic characteristics were age (18–24; 25–39; 40–54; 55+ years), gender (male; female), education (low: primary/secondary/vocational school; medium: education at college/university below degree level; high: university/post-graduate degree) and annual household income (low:  $\leq$ £15 000; medium: £15 000–£30 000; high:  $>$ £30 000). Smoking characteristics were cigarettes smoked per day, motivation to stop smoking (no/weak motivation; strong; predictive validity of attempting to stop smoking in the next year:  $ROC_{AUC} = 0.68$  [28]) and last quit attempt (unassisted; self-help; alternative nicotine; professional support).

### *Data analyses*

Latent modelling assumes that a population can be divided into mutually exclusive latent classes/groups based on its members' responses to categorical indicators [29]. Latent transition analysis expands this approach to longitudinal data. Key estimates in latent transition analysis are latent class membership, item-response probabilities and transition probabilities [30]. Latent class membership estimates what proportion of a population belongs to different latent classes at a measurement point, item-response probabilities describe response patterns specific to latent class and transition probabilities assess the likelihood of changing latent class at follow-up observations [16].

For the first aim, latent transition analysis differentiated participants' groups based on smoking, e-cigarette and nicotine use, urges to smoke and last quit attempt. We followed a stepwise procedure [31]. First, we

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**Box 1 MEASURES OF PARTICIPANTS' SMOKING, NICOTINE USE AND QUITTING BEHAVIOUR**


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**Smoking status**

**Could you please tell us which of the following best applies to you now?**

1. I smoke cigarettes (including hand-rolled) every day
2. I smoke cigarettes (including hand-rolled), but not every day
3. I do not smoke cigarettes at all, but I do smoke tobacco of some kind (e.g. pipe or cigar)
4. I have stopped smoking completely in the last year
5. I stopped smoking completely more than a year ago
6. I have never been a smoker

Categorised as 'ex-smoker' (4), 'non-daily smoker' (2) or 'daily smoker' (1).

**Vaping status**

**Could you please tell us which of the following best applies to you now?**

1. I currently vape/use e-cigarettes daily
2. I currently vape/use e-cigarettes but not every day
3. I have tried vaping/an e-cigarette once or a few times
4. I stopped vaping/using e-cigarettes since the last year
5. I stopped vaping/using e-cigarettes over a year ago
6. I have never vaped/used e-cigarettes

Categorised as 'non-user' (3–6), 'non-daily' (2) or 'daily' (1).

**Nicotine replacement therapy (NRT) use**

Participants were asked three questions to determine NRT use

- 1. Which, if any, of the following are you currently trying to help you cut down the amount you smoke?**
- 2. Do you regularly use any of the following in situations where you are not allowed to smoke?**
- 3. Can I check, are you using any of the following for any reason at all?**

1. Nicotine gum
2. Nicotine replacement lozenge/tablet
3. Nicotine replacement inhaler/inhalator
4. Nicotine replacement nasal spray
5. Nicotine patch
6. Electronic cigarette or vaping device <sup>1</sup>
7. Nicotine mouthspray
8. Another nicotine product

Categorised as 'user' (yes to at least one from 1–8 in any of the three questions) or 'non-user' (no to 1–8 in all three questions).

**Urges to smoke**

Participants were asked two questions to determine urges to smoke

- 1. How much of the time have you felt the urge to smoke in the past 24 h?**
  - 1.1 Not at all
  - 1.2 A little of the time
  - 1.3 Some of the time
  - 1.4 A lot of the time
  - 1.5 Almost all of the time
  - 1.6 All of the time
- 2. In general, how strong have the urges to smoke been?**
  - 2.1. Slight
  - 2.2. Moderate
  - 2.3. Strong
  - 2.4. Very strong
  - 2.5. Extremely strong

Categorised as 'no/slight to moderate' (1.1–1.6, 2.1–2.2) or 'strong to extreme' (1.2–1.6, 2.3–2.5).

**Last quit attempt**

Participants were asked two questions to determine type of support used in their last quit attempt.

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*Continued*

## Box 1 MEASURES OF PARTICIPANTS' SMOKING, NICOTINE USE AND QUITTING BEHAVIOUR—CONT'D

### 1. How many serious attempts to quit smoking (if any) have you made in the last 12 months?

- 1.1. None
- 1.2. One
- 1.3. Two
- 1.4. Three or more

### 2. Which, if any, of the following did you try to help you quit smoking during the most recent serious quit attempt?\*

- 2.1. None of these/did not use anything
- 2.2. Nicotine replacement product (e.g. patches/gum/inhaler) without a prescription
- 2.3. Nicotine replacement product on prescription or given to you by a health professional
- 2.4. Zyban (bupropion)
- 2.5. Champix (varenicline)
- 2.6. Attended a Stop Smoking group
- 2.7. Attended one or more Stop Smoking one-to-one counselling/advice/support session(s)
- 2.8. Phoned a Smoking Helpline
- 2.9. A book or booklet
- 2.10. Visited <https://quitnow.smokefree.nhs.uk/> website
- 2.11. Visited a website other than Smokefree
- 2.12. Used an application ('app') on a handheld computer (smartphone, tablet, PDA)
- 2.13. Hypnotherapy
- 2.14. Acupuncture
- 2.15. Electronic cigarette or vaping device
- 2.16. Other

\* Participants could have used more than one cessation aid

For latent class and transition analyses, categorised as 'did not try' (1.1), 'tried unassisted' (1.2–1.4, 2.1), 'tried assisted' (1.2–1.4, any of 2.2–2.16).

For descriptive analysis of 2016 data, further categorised as 'unassisted' (2.1), 'self-help' (2.9–2.14, 2.16), 'alternative nicotine' (2.2, 2.15) or 'professional support' (2.3–2.8).

### Motivation to stop smoking (MTSS)

#### Which of the following best describes you?

1. I REALLY want to stop smoking and intend to in the next month
2. I REALLY want to stop smoking and intend to in the next 3 months
3. I want to stop smoking and hope to soon
4. I REALLY want to stop smoking but I do not know when I will
5. I want to stop smoking but have not thought about when
6. I think I should stop smoking but do not really want to
7. I do not want to stop smoking
8. Do not know

For descriptive analysis of 2016 data, categorised as 'no/weak motivation' (3–8) or 'strong motivation' (1–2).

identified latent class models that best fit study data in both waves. Then, we looked for a latent transition model that best described data from both waves. At each step, we fit two to eight latent class and latent transition models and used 500 sets of random starting values allowing up to 100 iterations to identify the maximum likelihood solution for each model [32]. Latent transition analysis assumes data to be missing at random, and instead of missing cases for categorical indicators the average effect of non-missing values are used [32]. Initially, the absolute fit of latent class models was assessed by comparing each model's likelihood-ratio  $G^2$  statistic with the  $\chi^2$  distribution matching degrees of freedom in the model. A  $P$ -value above 0.05 indicated

that a model fit the data [16]. Models that fit the data in absolute terms were then compared by relative fit using Bayesian [33] and consistent Akaike's [34] information criteria. A smaller value of a criterion represents better balance between a model's fit and parsimony [16]. We also used entropy statistic ranging from 0 to 1 with higher value denoting better quality of classification [35].

For the second aim, we identified and explored the best-fitting latent transition model. Due to sparseness of longitudinal data [16,32], only Bayesian information criteria, consistent Akaike's information criteria and entropy were used to compare absolute and relative fit of different models. The best-fitting latent transition

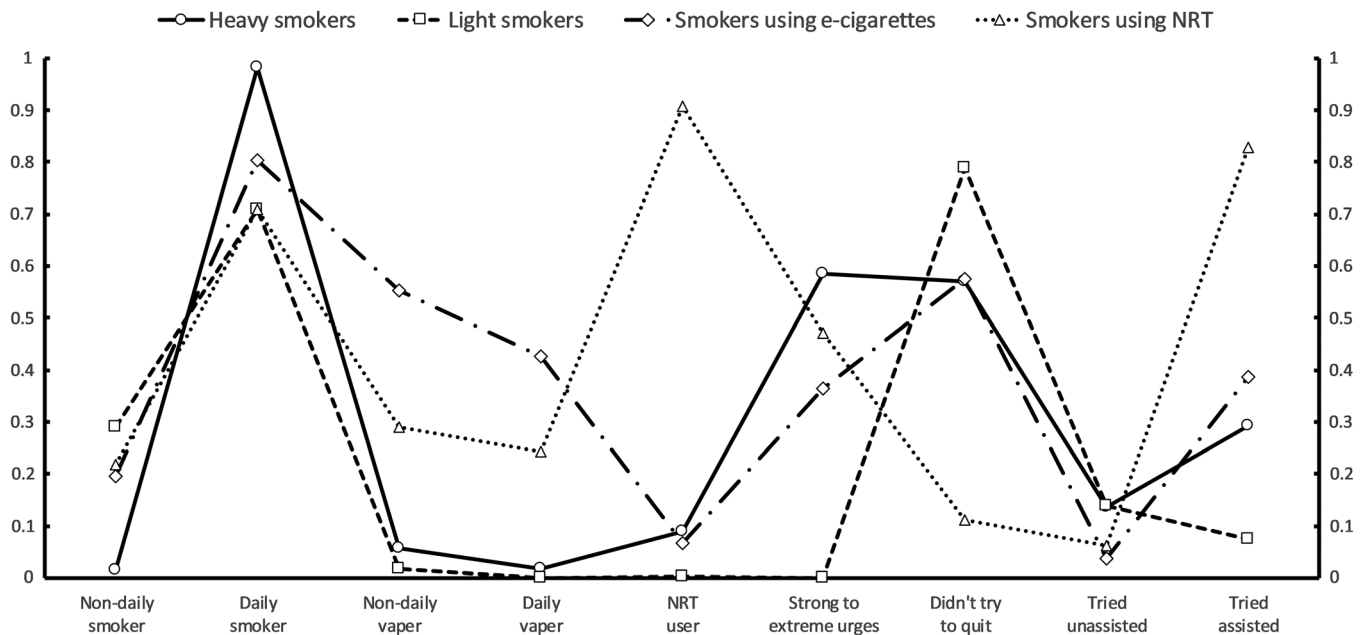


Figure 1. Item-response probabilities of smokers' groups. NRT (nicotine replacement therapy).

model was tested for measurement invariance [36] and varying transition probabilities between waves [31] (Table S2).

We compared latent groups' sociodemographic and smoking characteristics in 2016 using Pearson's  $\chi^2$  and Cramer's V statistics [37]. Adjusted residuals larger than  $|2.58|$  ( $\alpha = 0.01$ ) were used to identify cells contributing to differences between groups in  $\chi^2$  tests [38]. Similarly, we compared participants by their follow-up status to assess which characteristics were associated with follow-up data missing at random. Additionally, we computed frequencies of latent transition indicators for 2016 and 2017.

Latent Gold 5.1.0 [32] was used for latent modelling, R and SPSS Statistics 24 were used for descriptive analyses.

## Results

Separately for data from both waves, latent class models with six to eight classes showed good absolute fit, and 6-class models had the best relative fit at both waves (Table S1).

Among latent transition models, Bayesian information criteria preferred the 7-class, consistent Akaike's information criteria indicated the 6-class and entropy was equal between the two (Table S2). Based on latent class analyses and parsimony, we chose the 6-class latent transition model as the best fit for longitudinal data.

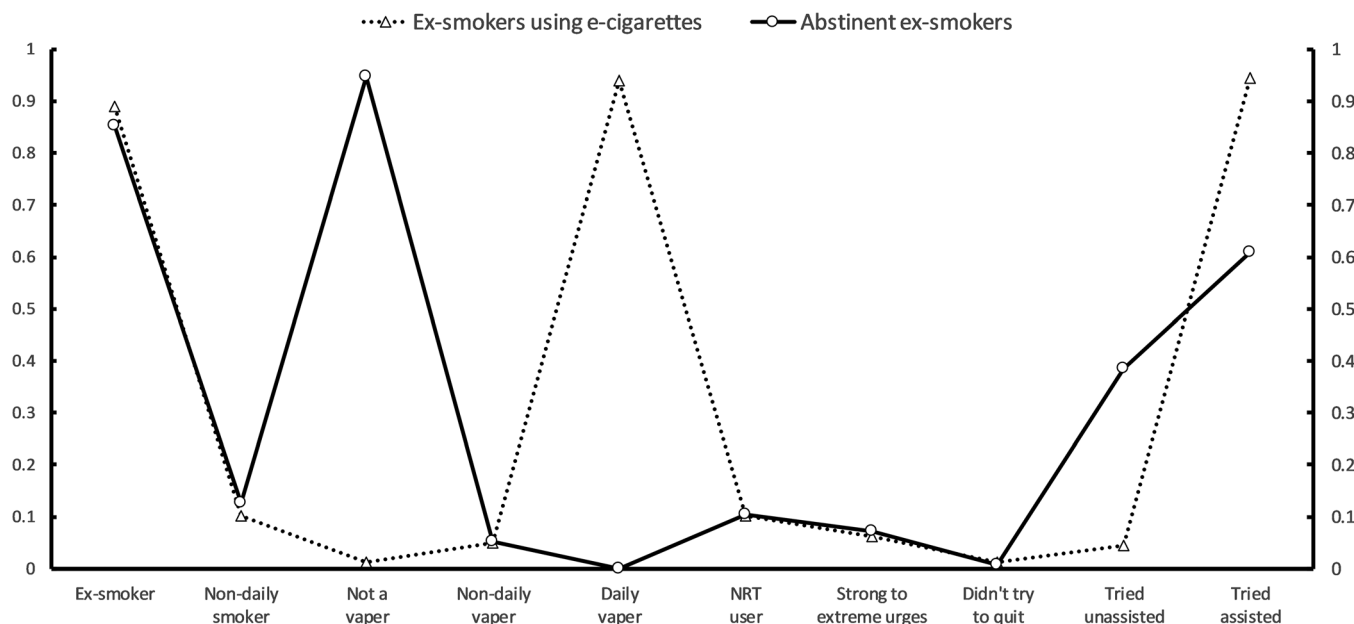
### Prevalence and characteristics of latent groups

In the latent transition model, four groups consisted mostly of smokers (*heavy smokers*, *light smokers*, *smokers using NRT* and *smokers using e-cigarettes*; Figure 1) and two of recent quitters (*abstinent ex-smokers* and *ex-smokers using e-cigarettes*; Figure 2).

*Heavy* and *light smokers* were the largest latent groups (28.2% and 20.8%, respectively) followed by *smokers using NRT* (19.5%) and *abstinent ex-smokers* (16.1%). The two smallest groups included participants who used e-cigarettes: *smokers using e-cigarettes* (8.6%) and *ex-smokers using e-cigarettes* (6.8%; Table 1).

*Heavy smokers* were daily smokers (probability of 98.3%) who were most likely to experience strong to extreme urges to smoke (58.6%). They also did not use e-cigarettes (92.5%) or NRT (91.1%; Table 1). Compared with other groups, *heavy smokers* on average smoked the most cigarettes per day (16.5, 95% confidence interval 15.86–17.09), earned less (64.0% had low or moderate income), were older (69.1% over 40 years old) and had lower education (76.6% with low or moderate education; Table 2).

*Light smokers* smoked less intensely (70.9% probability of daily, 29.0% of non-daily smoking) and reported exclusively no or weak urges to smoke (99.9%). They did not vape (98.2%), did not use NRT (99.9%) and were the least likely of all groups to have recently tried to quit smoking (21.2%; Table 1). Nearly two-thirds of *light smokers* were older than 40 (63.4%), mostly not



**Figure 2.** Item-response probabilities of ex-smokers' groups. NRT (nicotine replacement therapy).

motivated to quit smoking (91.5%) and smoked the fewest cigarettes of all smokers' groups (9.5, 95% confidence interval 8.9–10.1; Table 2).

*Smokers using NRT* were most likely daily smokers (70.8%) who used NRT (90.8%). They had a high probability of using e-cigarettes (53.3%) and having recently tried to quit smoking with support (82.7%; Table 1). Nearly half were 25–39 years old (44.4%), mostly with high income (56.1%) and high education (42.8%) and two-fifths were strongly motivated to quit (41.8%; Table 2).

*Smokers using e-cigarettes* smoked daily (80.4%) and used e-cigarettes non-daily (55.3%) or daily (42.7%). They did not use NRT (93.4%), experienced no or weak urges to smoke (63.7%) and most likely had not recently tried to quit smoking (57.5%; Table 1). Only 16.0% were strongly motivated to quit (Table 2).

*Abstinent ex-smokers* had recently quit smoking (85.2%), did not vape (94.8%) or use NRT (89.6%) and had tried quitting assisted (60.8%) or unassisted (38.5%; Table 1). Among all groups, *abstinent ex-smokers* included the highest proportion of 18–24-year-olds (16.7%; Table 2).

*Ex-smokers using e-cigarettes* had recently quit smoking (89.0%) and used e-cigarettes daily (93.9%). They did not use NRT (89.8%) and reported no or weak urges to smoke (93.8%; Table 1). Among all groups, they had the highest proportion of members who had recently tried to quit smoking using alternative nicotine (89.8%; Table 2).

#### Transitions between latent groups

In attrition analysis, older respondents were more likely to be followed-up: data were missing at random contingent on participants' age (Table S4).

Stability of latent groups varied: *heavy smokers* (86.6%) and *light smokers* (86.2%) had the highest probabilities of remaining in the same group at follow-up, while *smokers using e-cigarettes* were the least stable (75.3%; Table 1). Among smokers' groups, only the prevalence of *smokers using e-cigarettes* increased (+1.0%), while the *smokers using NRT* group reduced the most (−4.9%), followed by *heavy* (−2.8%) and *light smokers* (−1.0%). Recent quitters' groups increased: *ex-smokers using e-cigarettes* by 1.4% and *abstinent ex-smokers* by 6.3% (Table 1).

Among those who transitioned, the most probable transitions were from smokers' to ex-smokers' groups. *Light smokers* had 12.0% and *smokers using NRT* had 11.2% probability of transitioning to *abstinent ex-smokers* and *smokers using e-cigarettes* had 11.4% probability of moving to the *ex-smokers using e-cigarettes*' group (Table 1). Compared with *abstinent ex-smokers*, *ex-smokers using e-cigarettes* were more likely to change latent group at follow-up (17.8% and 23.1%, respectively), but less likely to relapse back to smoking (15.2% and 14.0%; Table 1). *Ex-smokers using e-cigarettes* had a 9.0% probability of quitting vaping and transitioning to *abstinent ex-smokers*, while the opposite transition was less likely (2.6%; Table 1). *Abstinent ex-smokers* were most likely to relapse to *light smokers* (6.7%), and *ex-smokers using e-cigarettes* to *smokers using e-cigarettes* (7.1%; Table 1).

**Table 1.** Six-class latent transition model of smoking and nicotine use and transitions between 2016 and 2017 (n = 2857)

	Latent status							
	Heavy smokers	Light smokers	Smokers using NRT	Smokers using e-cigs	Abstinent ex-smokers	Ex-smokers using e-cigs		
<i>Latent status prevalence</i>								
Overall	28.18%	20.76%	19.54%	8.64%	16.09%	6.78%		
2016	29.59%	21.25%	21.99%	8.14%	12.95%	6.08%		
2017	26.79%	20.27%	17.10%	9.13%	19.24%	7.47%		
Change	-2.80%	-0.98%	-4.89%	+0.99%	+6.29%	+1.39%		
<i>Item-response probabilities (response = yes)</i>								
	Heavy smokers	Light smokers	Smokers using NRT	Smokers using e-cigs	Abstinent ex-smokers	Ex-smokers using e-cigs	Overall	
<i>Smoking status</i>								
Ex-smoker	0.0017	0.0013	0.0747	0.0002	<b>0.8518</b>	<b>0.8903</b>	0.2128	
Non-daily	0.0155	0.2899	0.2172	0.1963	0.1264	0.1014	0.1512	
Daily	<b>0.9828</b>	<b>0.7087</b>	<b>0.7081</b>	<b>0.8035</b>	0.0218	0.0084	0.6360	
<i>Vaping status</i>								
No	<b>0.9253</b>	<b>0.9822</b>	0.4667	0.0203	<b>0.9480</b>	0.0113	0.7109	
Non-daily	0.0565	0.0177	0.2910	<b>0.5526</b>	0.0513	0.0503	0.1359	
Daily	0.0182	0.0001	0.2423	0.4271	0.0007	<b>0.9385</b>	0.1532	
<i>Use of NRT</i>								
Non-user	<b>0.9113</b>	<b>0.9985</b>	0.0921	<b>0.9336</b>	<b>0.8960</b>	<b>0.8980</b>	0.7678	
User	0.0887	0.0015	<b>0.9079</b>	0.0664	0.1040	0.1020	0.2322	
<i>Urges to smoke</i>								
No/slight to moderate	0.4137	<b>0.9993</b>	<b>0.5297</b>	<b>0.6368</b>	<b>0.9271</b>	<b>0.9377</b>	0.6953	
Strong to extreme	<b>0.5863</b>	0.0007	0.4703	0.3632	0.0729	0.0623	0.3047	
<i>Last quit attempt</i>								
Did not try	<b>0.5708</b>	<b>0.7883</b>	0.1122	<b>0.5754</b>	0.0071	0.0114	0.3981	
Tried unassisted	0.1362	0.1381	0.0608	0.0368	0.3847	0.0452	0.1471	
Tried assisted	0.2930	0.0736	<b>0.8270</b>	0.3878	<b>0.6081</b>	<b>0.9433</b>	0.4548	
<i>Transition probabilities</i>								
Latent status in 2017								
Latent status in 2016	Heavy smokers	Light smokers	Smokers using NRT	Smokers using e-cigs	Abstinent ex-smokers	Ex-smokers using e-cigs	Probabilities to quit <sup>a</sup>	Probabilities to relapse <sup>a</sup>
Heavy smokers	<b>0.8664</b>	0.0006	0.0026	0.0134	0.0859	0.0311	0.1170	–
Light smokers	0.0005	<b>0.8615</b>	0.0018	0.0156	<b>0.1199</b>	0.0007	0.1206	–
Smokers using NRT	0.0139	0.0227	<b>0.7673</b>	0.0574	<b>0.1120</b>	0.0268	0.1388	–
Smokers using e-cigs	0.0283	0.0437	0.0004	<b>0.7526</b>	0.0610	<b>0.1140</b>	0.1750	–
Abstinent ex-smokers	0.0393	0.0670	0.0005	0.0449	<b>0.8220</b>	0.0262	–	0.1517
Ex-smokers using e-cigs	0.0161	0.0362	0.0169	0.0710	0.0904	<b>0.7694</b>	–	0.1402

<sup>a</sup>Cumulative probabilities to transition from a smokers' group to non-smokers' groups ('probability to quit') or from a non-smokers' group to smokers' groups ('probability to relapse'). Among item-response probabilities, cells in **bold** indicate probabilities >50%. Among transition probabilities, cells in **bold** indicate probabilities >10%. E-cigs, electronic cigarettes; NRT, nicotine replacement therapy.

## Discussion

Latent transition analysis of the UK past-year smokers' data from 2016 to 2017 identified four

groups of smokers (*heavy and light smokers, smokers using NRT and smokers using e-cigarettes*) and two groups of participants who had recently quit smoking

**Table 2.** Sociodemographic and smoking characteristics in 2016 between participants in different latent groups (n = 2857)

	Latent classes							Cramer's V
	Overall	Heavy smokers	Light smokers	Smokers using NRT	Smokers using e-cigs	Abstinent ex-smokers	Ex-smokers using e-cigs	
N	2857	708	719	579	265	402	184	
Age, % (n)								
18–24	11.5% (319)	<b>7.9% (54)</b>	11.6% (81)	14.3% (80)	8.9% (23)	<b>16.7% (65)</b>	8.8% (16)	0.136
25–39	29.5% (819)	<b>23.0% (157)</b>	<b>25.0% (175)</b>	<b>44.4% (249)</b>	25.2% (65)	32.3% (126)	26.0% (47)	
40–54	31.5% (873)	35.5% (242)	30.4% (213)	27.3% (153)	35.3% (91)	26.7% (104)	38.7% (70)	
55+	27.5% (761)	<b>33.6% (229)</b>	<b>33.0% (231)</b>	<b>14.1% (79)</b>	30.6% (79)	24.4% (95)	26.5% (48)	
Missing	3.0% (85)	3.7% (26)	2.6% (19)	3.1% (18)	2.6% (7)	3.0% (12)	1.6% (3)	
Gender, % (n)								
Female	46.0% (1313)	50.3% (356)	49.5% (356)	<b>39.2% (227)</b>	41.9% (111)	49.0% (197)	35.9% (66)	0.103
Male	54.0% (1544)	49.7% (352)	50.5% (363)	<b>60.8% (352)</b>	58.1% (154)	51.0% (205)	64.1% (118)	
Education, % (n)								
Low	31.5% (884)	<b>38.2% (266)</b>	30.4% (214)	<b>25.1% (143)</b>	30.4% (80)	32.3% (126)	29.9% (55)	0.106
Moderate	36.7% (1029)	38.4% (267)	39.0% (274)	32.1% (183)	39.2% (103)	33.3% (130)	39.1% (72)	
High	31.8% (893)	<b>23.4% (163)</b>	30.6% (215)	<b>42.8% (244)</b>	30.4% (80)	34.4% (134)	31.0% (57)	
Missing	1.8% (51)	1.7% (12)	2.2% (16)	1.6% (9)	0.8% (2)	3.0% (12)	(0)	
Income, % (n)								
Low	22.4% (590)	<b>29.0% (188)</b>	23.3% (151)	<b>16.5% (91)</b>	19.4% (48)	20.9% (76)	21.4% (36)	0.109
Moderate	32.7% (859)	34.4% (223)	36.1% (234)	<b>27.5% (152)</b>	36.4% (90)	30.2% (110)	29.8% (50)	
High	44.9% (1180)	<b>36.7% (238)</b>	40.6% (263)	<b>56.1% (310)</b>	44.1% (109)	48.9% (178)	48.8% (82)	
Missing	8.0% (228)	8.3% (59)	9.9% (71)	4.5% (26)	6.8% (18)	9.5% (38)	8.7% (16)	
CPD, mean (95% CI)	12.45 (12.11, 12.80)	16.47(15.86, 17.09)	9.52(8.91, 10.13)	11.70(10.91, 12.49)	12.32(11.35, 13.28)	10.83(9.80, 11.87)	14.06(12.71, 15.40)	
Missing, % (n)	8.5% (243)	5.4% (38)	5.1% (37)	13.3% (77)	6.4% (17)	14.9% (60)	7.6% (14)	
MTSS <sup>a</sup> , % (n)								
Do not know/ weak	79.6% (1875)	<b>84.8% (599)</b>	<b>91.5% (653)</b>	<b>58.2% (322)</b>	84.0% (221)	74.1% (63)	<b>47.2% (17)</b>	0.330
Strong	20.4% (482)	<b>15.2% (107)</b>	<b>8.5% (61)</b>	<b>41.8% (231)</b>	16.0% (42)	25.9% (22)	<b>52.8% (19)</b>	
Missing	17.5% (500)	0.3% (2)	0.7% (5)	4.5% (26)	0.8% (2)	78.9% (317)	80.4% (148)	
Last quit attempt <sup>b</sup> , % (n)								
Did not try	38.6% (1104)	<b>48.3% (342)</b>	<b>76.5% (550)</b>	<b>8.5% (49)</b>	<b>51.7% (137)</b>	<b>5.2% (21)</b>	<b>2.7% (5)</b>	0.590
Unassisted	22.6% (386)	24.0% (88)	<b>73.4% (124)</b>	<b>4.0% (21)</b>	<b>6.3% (8)</b>	<b>39.0% (135)</b>	<b>6.0% (10)</b>	0.516
Self-help	37.4% (638)	35.2% (129)	<b>13.0% (22)</b>	<b>55.5% (294)</b>	37.5% (48)	32.4% (112)	<b>19.9% (33)</b>	0.290
Alternative nicotine	46.7% (797)	40.2% (147)	<b>9.5% (16)</b>	<b>54.0% (286)</b>	<b>80.5% (103)</b>	<b>27.7% (96)</b>	<b>89.8% (149)</b>	0.449
Professional support	19.6% (335)	16.4% (60)	<b>3.0% (5)</b>	<b>35.7% (189)</b>	<b>10.2% (13)</b>	17.3% (60)	<b>4.8% (8)</b>	0.297

Cells in **bold** are associated with adjusted residuals greater than  $\pm 2.58$ , they contribute to differences between groups in  $\chi^2$  tests when  $P < 0.01$ . <sup>a</sup>Only current smokers were asked about their motivation to stop smoking. <sup>b</sup>Multiple response options were possible for support used in the last quit attempt. CI, confidence interval; CPD, cigarettes smoked per day; e-cigs, electronic cigarettes; MTSS, motivation to stop smoking; NRT, nicotine replacement therapy.



(*abstinent ex-smokers* and *ex-smokers using e-cigarettes*). Nearly half of participants were *heavy* or *light smokers* who had not used alternative nicotine products and had largely not tried to quit smoking. E-cigarette users' groups grew slightly but remained the smallest at follow-up. Groups were relatively stable in the 16-month follow-up period. Among those who transitioned, smokers tended to quit smoking and move to the *abstinent ex-smokers*' group. Smokers who used alternative nicotine products had higher probabilities of transitioning: *smokers using e-cigarettes* had the highest probability of quitting smoking and *smokers using NRT* mostly transitioned to *abstinent ex-smokers*.

#### *Participants who did not use alternative nicotine products*

*Heavy* and *light smokers* were stable and intransigent: they had low odds of using alternative nicotine products, attempting to stop smoking and transitioning to *ex-smokers*' groups. *Heavy smokers* exemplified the endemic issue of smoking among the less affluent [39]: they were older, earned less, came from lower socioeconomic backgrounds and were least likely to quit smoking at follow-up. Around half of *heavy smokers* had recently attempted to quit smoking, but strong urges and weak motivation to stop smoking predisposed them to higher relapse risk.

*Light smokers* were the least likely to have attempted to quit smoking and did not use alternative nicotine. They resembled the low intensity smokers who do not escalate dependence on nicotine, do not experience withdrawal and smoke for pleasure, not for nicotine [40]. *Light smokers*' negligible odds of using NRT or e-cigarettes could be explained by reported lack of urges to smoke—nicotine cravings are not their primary motivation for smoking. Although lower dependence is associated with a higher success rate when quitting smoking [41], *light smokers* had only the second lowest transition probability of quitting smoking at follow-up. This was in accordance with research that compared successful quits of regular and light smokers [42] and suggests that *light smokers*' continued smoking is better explained by lower motivation or fewer attempts to quit than by nicotine dependence.

Much like *heavy* and *light smokers*, *abstinent ex-smokers* were also unlikely to use alternative nicotine products and had the highest probability of having tried to quit without assistance among all groups. The three groups were related in transitions: *light* and *heavy smokers* almost exclusively transitioned to *abstinent ex-smokers*, while *abstinent ex-smokers* mostly relapsed to

*light* smoking. Combined, all three groups comprised almost two-thirds of the sample, confirming that most smokers do not use alternative nicotine products. While transitioning to *abstinent ex-smokers* is the best possible option for smokers, a question how to prompt *heavy* and *light smokers*—half of the study sample—to do so successfully remains.

#### *Participants who used alternative nicotine products*

Alternative nicotine use was a distinctive characteristic of *smokers using NRT*, *smokers using e-cigarettes* and *ex-smokers using e-cigarettes* groups. Use of alternative nicotine products was associated with higher probability of changing latent group at follow-up. *Smokers using NRT* and *using e-cigarettes* had the second highest and the highest probabilities of giving up smoking, respectively. However, the number of *smokers* and *ex-smokers* who *used e-cigarettes* increased in size, while the number of *smokers using NRT* decreased the most over the follow-up period.

Participants from other latent groups had less than 2% probabilities of transitioning to *smokers using NRT*. This indicates how the prevalence of *smokers using NRT* plummeted at follow-up but does not explain the decline. Possibly, only particular smokers in the cohort were willing to use NRT alongside smoking. As in population-level findings [39], *smokers using NRT* were from higher socioeconomic backgrounds and had stronger motivation to use support when quitting smoking than others. Although the use of e-cigarettes has not affected NRT use on a population-level [43], it could have substituted NRT for some smokers from the studied cohort. *Smokers using NRT* had relatively high probabilities of using e-cigarettes and of transitioning to groups of *smokers* or *ex-smokers who use e-cigarettes*. Given the evidence on comparative efficacy of NRT and e-cigarettes [11], this was a positive switch for smokers motivated to quit smoking.

E-cigarette users were clustered within the two smallest groups of *smokers* and *ex-smokers*. *Smokers using e-cigarettes* were less likely to have tried quitting smoking and were mostly non-daily vapers, which corresponded with evidence that daily e-cigarette use is associated with quitting smoking [44]. *Smokers using e-cigarettes* also had the highest probability of quitting smoking and were the group to which *ex-smokers* most likely relapsed to (11.6% probability). Transitions to and from this group suggest that dual use is an intermediate and dynamic stage, where smokers might require further motivation and support to facilitate change towards quitting smoking.

Our findings supported the evidence that a considerable proportion of dual users continue using e-cigarettes

after quitting smoking [2,12], but also showed that *smokers using NRT* and *using e-cigarettes* had relatively high probabilities of transitioning to the *abstinent ex-smokers*' group. Although recent ex-smokers discontinue using NRT quicker than e-cigarettes [45], our findings affirm that dual e-cigarette use while smoking does not necessarily predispose to continued e-cigarette use after quitting smoking. Generally, these transitions attest that alternative nicotine products might help smokers to quit, prevent relapse and eventually aid the transition to abstinence from nicotine.

### Study limitations

A few limitations must be noted. First, latent transition analysis is an exploratory method without prior hypotheses about data structure [46]. A larger sample would empower it to differentiate more latent groups [16], so the groups we analysed are not definitive. However, we followed a recommended staged selection process [31], which led to a comprehensive six-class model.

Second, transitions between latent groups are contingent on the interim between baseline and follow-up observations. In our study, 16 months separated measures. Smokers can transition between smoking, quitting and relapse in a matter of days [47], so our model provides only a snapshot of participants' behaviour at two waves and does not account for multiple changes during the follow-up period. Due to a high relapse rate among smokers trying to quit each year [48], this might have overestimated the stability of smokers' groups.

Third, study data were self-reported. Participants' nicotine use was not verified biochemically but, as in other population studies [49,50], we presumed the self-reported data to be sufficiently valid. Also, the recall of the last quit attempt depends on participants' smoking status and time since the attempt [51]. Unsuccessful attempts are recalled less commonly [52], which could have inflated probabilities of not trying to quit in smokers' groups.

Finally, fewer younger participants were followed-up. This might have underestimated follow-up prevalences of groups that had more younger participants: *smokers using NRT* and *abstinent ex-smokers*. We also excluded participants who had been ex-smokers for more than a year or were pipe and cigar users, therefore, findings are relevant only to past-year cigarette (manufactured or roll-your-own) smokers.

Despite these limitations, our study is the first to evaluate transitions between groups of smokers and recent quitters from a nationally representative sample incorporating information on alternative nicotine product use and recent smoking cessation attempts.

### Implications and future research

Study findings showed that smokers differ, and some require more attention from clinicians. Around a half of participants were *heavy* or *light smokers*. They had the lowest odds of quitting smoking or using alternative nicotine products, which underscores a need for interventions that could reach these smokers [53]. This is particularly relevant to light smokers, who receive less attention by healthcare specialists than moderate-to-heavy smokers [54]. Despite the lowest probabilities to quit smoking, around one in 10 *heavy* and *light smokers* still transitioned to *abstinent ex-smokers*. Future studies could investigate what factors instigate positive changes among the most intransigent smokers.

Future research could investigate reasons behind the observed decline in *smokers using NRT*, who were most motivated to stop and to use cessation support. Contrary to NRT, e-cigarette use was increasing and was associated with changes in smoking behaviour at follow-up. Our findings support e-cigarettes' potential to reduce harm from smoking [14], but further research needs to investigate what groups of smokers are not interested in using alternative nicotine products.

### Conclusions

Four latent groups of smokers and two of recent quitters were identified from longitudinal UK cohort data. The groups were relatively stable within the 16-month study period. Nearly half continued smoking without attempts at quitting or harm reduction. Those who transitioned generally moved towards quitting smoking, with most abstaining from nicotine altogether. Use of e-cigarettes increased slightly and was associated with higher probabilities of transitioning away from smoking.

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## Conflict of Interest

The authors have no conflicts of interest.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

### Appendix S1: Supporting Information