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Prevalence and characteristics of smokers interested in using virtual reality for encouraging smoking cessation: a representative population survey in Great Britain

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Abstract

Background Cigarette smoking is one of the leading causes of morbidity in the world. Virtual reality (VR) has been used to encourage and support quit attempts. However, interest in VR may differ according to sociodemographic characteristics. This study aimed to estimate the proportion and associated characteristics of smokers in Great Britain who were interested in using VR for smoking cessation.

Methods Data were collected from 6,858 adults between February to April 2023, from the Smoking Toolkit Study—a monthly, nationally representative, cross-sectional survey of adults in Great Britain. Of these, 873 were smokers (unweighted). Prevalence of interest was assessed descriptively and associations between interest and sociodemographic and smoking characteristics were analysed with weighted logistic regression models.

Results Of 905 (weighted) smokers, 34.6% (95% Confidence Interval (CI):31.0%-38.5%) were interested in using VR for smoking cessation. Smokers had greater odds of reporting interest in VR for smoking cessation who were: highly motivated to quit (Odds Ratio (OR):2.41, 95% CI:1.59–3.65), had made a quit attempt in the past year (OR:1.95, 95% CI:1.37–2.77), currently trying to cut down (OR:1.90, 95% CI:1.34–2.67) and interested in VR generally (OR:10.42, 95% CI:6.97–15.57). Those ≥ 65 years old (OR:0.29, 95% CI:0.15–0.57) and women (OR:0.69, 95% CI:0.49–0.97) were less likely to report interest.

Conclusions The results of this study indicate that up to a third of adult smokers may be interested in using VR to support a quit attempt. However, the potential reach of a VR smoking cessation intervention may be lower in certain subgroups such as women, adults 65 years or older, and adults less motivated to quit. From a health equity perspective, it is recommended that non-digital but effective interventions should be made readily available for adults at risk of digital exclusion due to lack of interest. However, as VR grows in popularity and its technological potential

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becomes fully realised, future research could also focus on strategies to reduce digital exclusion and increase interest. For example, by involving these subgroups in co-design activities and using novel dissemination strategies.

Keywords Smoking, E-health, Cross-sectional studies, Virtual reality, Digital exclusion, Smoking cessation

Background

Cigarette smoking and tobacco use are the leading modifiable causes of ill health and mortality. There are currently 1.1 billion cigarette and tobacco users (hereafter referred to as smokers) globally and 6.4 million in the United Kingdom (UK) [1, 2]. Traditional interventions such as counselling or nicotine replacement therapy are effective in supporting smoking cessation [3]. However, the development of digital interventions such as websites, smartphone apps, wearables, serious video games and virtual reality (VR) has proliferated in the last decade, and they may be a useful addition to traditional support [4]. This study explores interest in using VR generally and for smoking cessation, among cigarette smokers in Great Britain.

VR involves wearing a headset, which is a device that presents images of a digitally rendered virtual environment (VE) on a screen. The screen completely covers the visual field and simulates changes in perspective in response to head movement, meaning the user can see across 360 degrees [5, 6]. Virtual reality has previously been used in interventions to support smoking cessation, such as cue exposure therapy (CET). CET involves repeatedly simulating smoking cues to elicit nicotine cravings in users, to unlearn the association between the smoking cue and the craving [7]. According to review evidence, while VR-CET shows promise, its effect on long-term abstinence has been inconsistent across trials [7]. While less studied, VR has also been used to encourage quit attempts in smokers by delivering immersive messages on the health consequences of smoking. These pilot studies showed greater abstinence rates in the intervention groups compared to the controls [8, 9]. However, to estimate the real-world impact of any VR smoking cessation intervention, "reach" should be considered alongside effect estimates. "Reach" refers to the proportion and characteristics of the target population that have access to and subsequently use the intervention [10].

Roger's (1995) "diffusion of innovations" theory describes how an innovation is differentially communicated through certain channels over time among different members of a social system [11]. The advantages of a new digital innovation, such as VR, are not always clear to the intended users at the outset, before seeing the benefits through, for example, others' VR use. Despite the appearance (and disappearance) of commercially available VR headsets since the 1990s, current ownership and experiences using VR are still relatively rare [12]. In a 2021 nationally representative survey of 3,544 British internet users, only 4% of respondents owned a VR headset, suggesting that the adoption rate is still low [13]. There is a paucity of data gauging interest in using VR for encouraging or supporting smoking cessation, likely due to a lack of commercially available products. The diffusion of new technologies that have a preventative purpose is usually slow because the user reaps the rewards in the future [14]. In contrast, if the benefits are more immediate to the user (e.g., VR for entertainment) the adoption rate is faster [14]. UK and European survey data from 2021 indicate that the most popular VR activities are playing video games and watching films, concerts, or sporting events [15, 16].

Communication about new technologies typically occurs through mass media and interpersonal communication [14]. However, knowledge transfer that shapes attitudes towards new technology is more likely to reach and be effective among individuals who have similar backgrounds (social grade, beliefs, age etc.) [11]. Those who are more digitally experienced are less likely to effectively communicate with less digitally experienced individuals. Therefore, the adoption of a new smoking cessation VR intervention runs the risk of staying concentrated within certain subgroups, particularly those who are more socially advantaged and younger (digital exclusion). Older individuals are more likely to be digitally excluded and use technology less [17]. However, across all age groups, indicators of social disadvantage (e.g., low literacy or low educational attainment) are the strongest predictor of internet access and use. Adults in the most socioeconomically disadvantaged groups are three times more likely to be "limited users" of the internet compared to those who are most advantaged [18].

Digital exclusion intersects with other forms of health inequalities. Regarding age, smoking prevalence is lowest in those over 65 years (estimated prevalence of 8% in Great Britain) and highest in the 25–34 age group (16.3%) [1]. However, some studies suggest that older adults may be less likely to report a quit attempt and may have age-specific resistance to quitting (for example, the idea that the damage is already done or that their older age is an indicator of "survivorship") [19]. In contrast, while there appears to be no social gradient in the initiation of quit attempts, there is a large socioeconomic gap in quit success, with individuals in

England from the lowest social grade having around half the quit success rate of those from the highest social grade (11.4% vs 20.4%) [20, 21]. However, data from a nationally representative cross-sectional survey of English smokers suggests that there was no significant difference in the use of a digital aid during the most recent quit attempt according to social grade [22]. Nevertheless, technology-based interventions should aim to reach as wide and diverse an audience as possible to avoid reproducing and reinforcing existing health inequities [23]. However, due to a lack of data, it is not yet clear if levels of interest in VR for smoking cessation across subgroups mirror typical patterns of digital exclusion. Identifying demographic and smoking characteristics associated with interest in VR will help future intervention development in several regards, including the tailoring of content for specific target groups or creating additional dissemination strategies for groups that may be at risk of digital exclusion.

This study addressed the following research questions (RQ):

RQ1. What is the prevalence of interest in using a VR headset:

i. for any purpose?
ii. to encourage or support smoking cessation?

RQ2. How does the prevalence of these interests differ according to sociodemographic and smoking characteristics and past use of a digital smoking cessation aid?

Methods

Study design and setting

The "Strengthening the Reporting of Observational Studies in Epidemiology" guidelines informed the design and reporting of this study [24]. The protocol and analysis plan were preregistered using the Open Science Framework (https://osf.io/ma675). This study used data from the ongoing Smoking Toolkit Study (STS), which is a monthly, cross-sectional survey [25–27]. The STS uses a hybrid of random probability and simple quota sampling to select a new sample of approximately 2,400 adults (18 years and over) each month. Before March 2020 data was collected via computer-assisted face-to-face interviews. However, from April 2020 onwards, data has been collected via telephone. Comparisons of the two data collection methods indicate good comparability [28]. Additional details of the STS and the sampling procedure are provided elsewhere [27].

Sample size

RQ1 relates to estimates of prevalence. Based on previous estimates of interest in using VR in the general UK population, we initially calculated that a sample size of 1,053 was required to estimate a true prevalence of up to 47%, with 95% confidence and ± 3% precision [29]. However, available resources required us to amend this calculation to a precision of ± 4%, to give a required sample size of 599 [30]. This amendment was done before data collection. To account for potential missing responses, this study collected data across three STS survey waves (three months) between February and April 2023, resulting in data from a total of 873 smokers (unweighted).

Participants

In the sample, current smokers were defined as those who responded a, b, or c to the following question: "Which of the following best applies to you? Please note we are referring to cigarettes and other kinds of tobacco that you set light to and NOT electronic or 'heat-not-burn' cigarette" a.) I smoke cigarettes (including hand-rolled) every day, b.) I smoke cigarettes (including hand-rolled), but not every day, c.) I do not smoke cigarettes at all, but I do smoke tobacco of some kind (e.g., Pipe, cigar, or shisha), d.) I have stopped smoking completely in the last year, e.) I stopped smoking completely more than a year ago, and f.) I have never been a smoker (i.e., smoked for a year or more).

Variables

For current smokers, the outcome variables were the proportion who reported interest in using VR for any purpose and the proportion who reported interest in using VR specifically for smoking cessation. This was measured by asking, "By a virtual reality (VR) headset we mean an electronic device that you wear on your head with a screen inside that allows you to see seemingly real images in 3D. People commonly use VR headsets to play games, watch films or sports, learn new skills, experience culture, and use social media. If you had free access to a VR experience, would you be interested in ever using a headset?". Also, "Again, if you had free access to use a headset, would you be interested in receiving a VR experience focused on providing advice or support to quit smoking?" In this study, we judged this question on 'providing advice or support' to reflect people's interest in VR to encourage or support cessation. For both questions, the response options were 1.) very interested, 2.) interested, 3.) uninterested, 4.) very uninterested, 5.) don't know. Response options were dichotomised into "interested" (options 1 and 2) and "uninterested" (options 3, 4 and 5).

The sociodemographic characteristics of interest were: age (16–24/ 25–34/ 35–44/ 45–54/ 55–64/ 65 + years), gender (women/ men), educational level (post-16 educational qualifications/ no post-16 qualifications) and social grade, as assessed by the National Readership Survey's Social Grade Classification Tool (ABC1 /C2DE) [31]. ABC1 corresponds to managerial, professional, and intermediate occupations, while C2DE refers to small employers and own account workers, lower supervisory and technical occupations, and semi-routine and routine occupations, never workers and long-term unemployed. This occupational measure of social grade is a valid index of socioeconomic status and is especially relevant in the context of smoking [21].

Smoking characteristics included motivation to quit, as measured by the Motivation to Stop Scale (MTSS) [32]. The MTSS has the following response options: 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 REALLY want to stop smoking, but I don't know when I will; 4.) I want to stop smoking and hope to soon; 5.) I want to stop smoking but haven't thought about when; 6.) I think I should stop smoking but don't really want to; and 7.) I don't want to stop smoking. Responses were dichotomised into high (1–2) and low motivation (3–7 and any response of "I don't know"). Also assessed was whether respondents were currently trying to cut down the number of cigarettes smoked (yes/ no) and the number of serious attempts to stop smoking in the past 12 months (none/ at least one attempt).

Past experiences using a digital aid for smoking cessation were measured by asking, "What was used to try to help stop smoking during the most recent serious quit attempt?" Response options: "Visited www.nhs.uk/smokefree website", "Visited a website other than smokefree" and "Used an application on a handheld computer (smartphone, tablet or PDA)" were categorised as having past digital experience. Any response that did not include these options were classified as not having used a digital smoking cessation aid. As this question is only asked to smokers who have made a quit attempt in the past year, missing data were imputed as not having used a digital smoking cessation aid.

Statistical analysis

The data analysis was conducted in STATA 17.0. For all research questions, the data were weighted using the rim (marginal) technique to match the sample to the proportions of the British population on the dimensions of region, age, social grade, ethnicity, housing tenure and working status within sex [33]. We conducted complete case analyses for all research questions, as less than 5% of values for the included variables were missing. For gender, we also excluded observations for "in another way" due to low numbers.

For RQ1, the proportion and 95% Confidence Intervals (CI) of interest in using VR generally and for smoking cessation were calculated for each predictor variable.

For RQ2 we calculated the unadjusted associations between interest in VR for any purpose and the predictor variables described above in a series of logistic regression models. The unadjusted associations between interest in using VR to encourage smoking cessation and the same predictor variables were also assessed in a series of logistic regression models. The level of significance was set at $P<0.05$. Odds ratios (OR) and precise p-values were reported.

In sensitivity analyses for RQ1 and RQ2: i.) the main analysis was repeated on unweighted data and ii.) the two outcome variables were treated continuously, measuring the level of interest on a scale of 0–3 (responses: 0 = very uninterested, 1 = uninterested, 2 = interested, 3 = very interested). A higher score corresponded to a greater degree of interest. The weighted linear regression used the same set of predictor variables as the main analysis and excluded responses of "I don't know".

Changes from registration

Post-registration of the protocol, the wording of RQ1 was amended slightly to include the addition of "or support". This was to better reflect the wording of the data collection questions given to respondents in the STS survey.

Unplanned analysis

Subsequent qualitative work that is part of this study's larger project suggested that age was an important demographic factor regarding interest and use of VR for smoking cessation. Older smokers in co-design focus groups did not see themselves as "digital natives" [34]. Additionally, given the size of the association between age and interest in VR for smoking cessation (compared to other demographic variables) in the descriptive analysis, we conducted an unplanned analysis to explore independent associations between age and interest. We selected confounding variables for the adjusted logistic regression model based on the results of unadjusted analysis for RQ2 and subject knowledge [35]. We constructed a directed acyclic graph (DAG) using DAGitty v3.1 to understand potential mechanisms better, make assumptions explicit and differentiate between potential confounders and mediators [36, 37]. Figure 1 shows the DAG which consists of both measured and unmeasured variables. The logistic regression model was adjusted for social grade and gender.

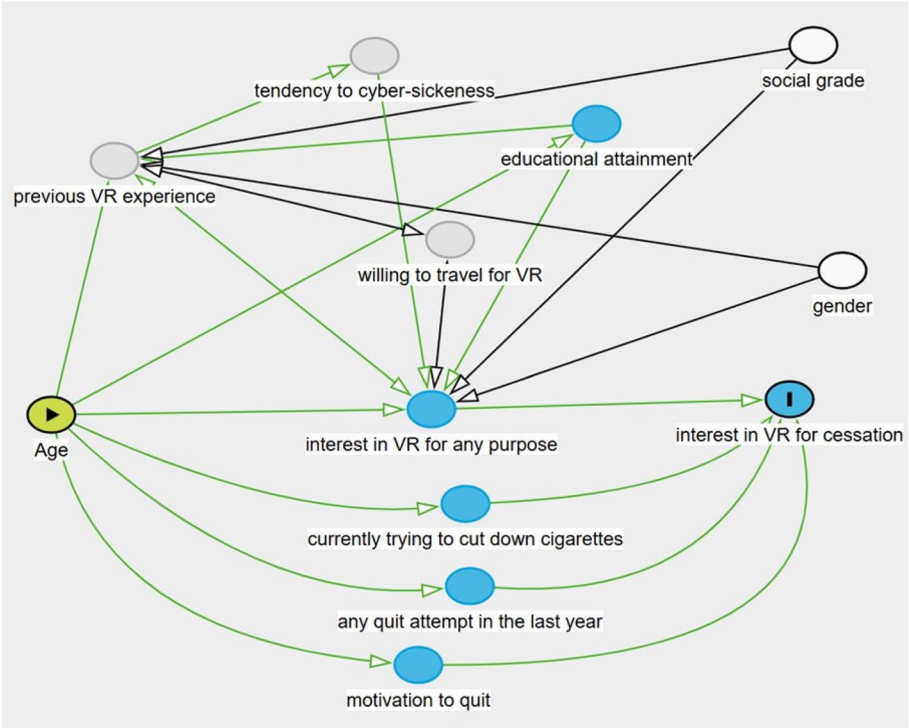

Fig. 1 Directed acyclic graph (DAG) demonstrating the pathways associated with age (green node) and interest in VR for smoking cessation (blue node with bold outline). White nodes represented adjusted variables. Grey nodes represent unmeasured variables. Other blue nodes represent mediators. The green arrows represent the various causal pathways. Some arrows are bi-directional. While the arrows pointing towards interest in VR for any purpose may factor directly into an interest in VR for smoking cessation, this likely represents a small subset of the population, and these arrows were omitted for clarity. The absence of pink lines suggests that this model is sufficiently adjusted

In addition to this, we also looked further into the associations between gender and social grade and interest in VR for encouraging and supporting smoking cessation, by stratifying results according to age group [38].

Results

A total of 6,858 adults were surveyed between February and April 2023 of whom 873 were smokers. Data for gender and number of quit attempts were missing for 39 respondents and an additional 14 identified as "in another way". Therefore, data from 820 smokers was included in the analysis. Table 1 shows the weighted and unweighted characteristics of the sample. In the weighted sample, there was a slightly higher proportion of men (55.0%) compared to women and respondents from a less advantaged social grade (58.7%). However, 77.9% had a post-16 educational qualification. The proportion of the sample that had made a quit attempt in the past year was 32.1% and only 1.6% had used a digital smoking cessation aid in the past year.

In the weighted analysis, 50.2% (95% CI: 46.4%-54.1%) of the sample were interested in using VR for any purpose, while 34.6% (95% CI: 31.0%-38.5%) of the sample were interested in using VR specifically for encouraging and supporting smoking cessation. Table 2 shows interest in VR generally and interest in VR for smoking cessation by the sample's sociodemographic, smoking, and digital health experience characteristics. Smokers had greater odds of reporting a general interest in using VR who were: younger (Odds Ratio (OR):0.73, 95% CI: 0.40 -1.31), had a post-16 educational qualification (OR: 2.09, 95% CI: 1.41–3.07) or had made at least one quit attempt in the last year (OR 1.72, 95% CI: 1.22–2.43). Women had reduced odds of reporting general interest in VR (OR 0.47, 95% CI: 0.34–0.64).

Smokers had greater odds of reporting an interest in using VR specifically for encouraging and supporting cessation who were: highly motivated to quit (OR 2.41, 95% CI: 1.59–3.65), had made at least one quit attempt in the past year (OR: 1.95, 95% CI: 1.37–2.77), currently trying to cut down (OR 1.90, 95% CI: 1.34-2.67) or interested in VR generally (OR 10.42, 95% CI 6.97 -15.57). Women (OR 0.69, 95% CI: 0.49–0.97) and those 65 years and older (OR 0.29, 95% CI: 0.15–0.57) had lower odds of reporting interest in VR for smoking cessation. For educational attainment, there was

Table 1 Sample characteristics unweighted *N* = 820, weighted *N* = 905

	Unweighted N = 820	Weighted N = 905
Age % (n)		
16–24	13.5 (111)	15.4 (140)
25–34	18.2 (149)	23.0 (208)
35–44	15.2 (125)	16.2 (147)
45–54	17.7 (145)	15.6 (141)
55–64	17.9 (147)	15.0 (136)
65 +	17.4 (143)	14.7 (132)
Gender % (n)		
Men	54.8 (449)	55.0 (497)
Women	45.2 (371)	45.0 (408)
Education % (n)		
No post-16 qualifications	22.3 (183)	22.1 (200)
Post-16 qualifications	77.7 (637)	77.9 (705)
Social grade [a] % (n)		
C2DE	44.9 (368)	58.7 (531)
ABC1	55.1 (452)	41.3 (374)
Motivation to quit % (n)		
Low	82.3 (675)	82.7 (749)
High	17.7 (145)	17.3 (156)
Quit attempts in the last year % (n)		
None	69.9 (573)	67.9 (615)
At least one	30.1 (247)	32.1 (290)
Currently trying to cut down but not quit % (n)		
No	45.0 (369)	45.4 (411)
Yes	55.0 (451)	54.6 (494)
Interest in using VR for general purposes % (n)		
Very interested	22.4 (184)	23.5 (212)
Interested	27.1 (222)	26.8 (242)
Uninterested	18.8 (154)	18.2 (165)
Very uninterested	27.7 (227)	26.6 (241)
Do not know	4.0 (33)	4.9 (44)
Interest in using VR for encouraging and supporting cessation % (n)		
Very interested	12.9 (106)	14.2 (128)
Interested	19.9 (163)	20.4 (185)
Uninterested	26.6 (218)	25.6 (232)
Very uninterested	37.2 (305)	36.5 (330)
Do not know	3.4 (28)	3.3 (30)
Used a digital smoking cessation aid in the last year % (n)		
No	98.3 (806)	98.4 (890)
Yes	1.7 (14)	1.6 (15)

[a] ABC1 corresponds to managerial, professional, and intermediate occupations. C2DE refers to small employers and own account workers, lower supervisory and technical occupations, semi-routine and routine occupations, never workers and long-term unemployed

an uncertain association with people who had post-16 educational qualifications appearing to have greater odds of reporting interest in VR for smoking cessation (OR: 1.50, 95% CI: 0.99–2.28). The pattern of these results was largely similar for the unweighted analysis and when interest in VR was treated continuously (supplementary Table 1 and supplementary Table 2).

In the unplanned analyses looking specifically at age group (Table 3), smokers who were 65 years or older were less likely than the youngest age group to be

Table 2 Unadjusted logistic regression models predicting interest in VR generally and for smoking cessation

	General interest in using VR for any purpose			Interest in using VR for smoking cessation		
	% Interested (454/905)	OR (95% CI)	*P*-value	% Interested (313/905)	OR (95% CI)	*P*-value
Age % (n/N)						
16–24	67.8 (95/140)	1 (ref)	-	37.4 (52/140)	1 (ref)	-
25–34	60.5 (126/208)	0.73 (0.40 -1.31)	0.290	37.8 (79/208)	1.01 (0.57–1.81)	0.956
35–44	59.3 (87/147)	0.69 (0.38–1.26)	0.227	43.2 (64/147)	1.28 (0.71–2.30)	0.419
45–54	51.8 (74/141)	0.51 (0.28–0.92)	0.024	38.4 (54/141)	1.04 (0.59–1.86)	0.881
55–64	38.7 (53/136)	0.30 (0.17–0.54)	< 0.001	32.5 (44/136)	0.81 (0.45–1.45)	0.474
65 +	15.6 (21/132)	0.09 (0.05–0.17)	< 0.001	14.9 (20/132)	0.29 (0.15–0.57)	< 0.001
Gender % (n/N)						
Men	58.7 (292/497)	1 (ref)	-	38.3 (191/497)	1 (ref)	-
Women	39.9 (163/408)	0.47 (0.34–0.64)	< 0.001	30.1 (123/408)	0.69 (0.49–0.97)	0.031
Education % (n/N)						
No post-16 qualifications	36.2 (73/200)	1 (ref)	-	27.7 (55/200)	1 (ref)	-
Post-16 qualifications	54.2 (382/705)	2.09 (1.41–3.07)	< 0.001	36.5 (258/705)	1.50 (0.99–2.28)	0.055
Social grade % (n/N)						
C2DE	47.1 (250/531)	1 (ref)	-	36.6 (195/531)	1 (ref)	-
ABC1	54.7 (204/374)	1.35 (1.00–1.83)	0.051	31.8 (191/374)	0.80 (0.59–1.11)	0.188
Motivation to quit % (n/N)						
Low	48.7 (364/749)	1 (ref)	-	31.0 (232/749)	1 (ref)	-
High	57.9 (90/156)	1.45 (0.96–2.18)	0.076	52.0 (81/156)	2.41 (1.59–3.65)	< 0.001
Quit attempts in the last year % (n/N)						
None	45.9 (282/615)	1 (ref)	-	29.7 (182/615)	1 (ref)	-
At least one	59.4 (172/290)	1.72 (1.22–2.43)	0.002	45.1 (131/290)	1.95 (1.37–2.77)	< 0.001
Currently trying to cut down but not quit % (n/N)						
No	47.6 (195/ 411)	1 (ref)	-	26.8 (110/411)	1 (ref)	-
Yes	52.5 (260/494)	1.22 (0.89–1.67)	0.219	41.1 (203/494)	1.90 (1.34- 2.67)	< 0.001
Interest in using VR for general purpose % (n/N)						
Uninterested	–	–	–	11.5 (52/450)	1 (ref)	-
Interested	–	–	–	57.5 (262/454)	10.42 (6.97 -15.57)	< 0.001
Used a digital smoking cessation aid in the last year % (n/N)						
No	50.1 (446/890)	1 (ref)	-	34.4 (306/890)	1 (ref)	-
Yes	61.6 (9/15)	1.60 (0.49–5.18)	0.433	48.7 (7/15)	1.81 (0.54- 6.14)	0.339

Table 3 Logistic regression model for the association between age and VR for smoking cessation, adjusted for gender and social grade

Age group	OR (95% CIs)	*P*-value	OR adjusted (95% CIs)	*P*-value
16–24	1 (ref)	-	1 (ref)	-
25–34	1.01 (0.57–1.81)	0.956	1.04 (0.57 – 1.86)	0.907
35–44	1.28 (0.71–2.30)	0.419	1.37 (0.76- 2.48)	0.293
45–54	1.04 (0.59–1.86)	0.881	1.09 (0.61 – 1.94)	0.780
55–64	0.81 (0.45–1.45)	0.474	0.82 (0.46 – 1.49)	0.520
65 +	0.29 (0.15–0.57)	< 0.001	0.31 (0.16–0.60)	0.001

interested in using VR specifically for smoking cessation, when accounting for gender and social grade (OR adjusted:0.31, 95% CI: 0.16–0.60).

Furthermore, gender differences in interest in VR for smoking cessation were most pronounced in the 35–44 age group, when adjusted for social grade (OR adjusted: 0.33, 95% CI: 0.15–0.78), but non-significant in other age groups (supplementary Table 3). In the unplanned analysis, associations between social grade and interest in VR for smoking cessation remained non-significant when stratified by age group, except in the 55–64 age group (OR adjusted: 0.33, 95% CI: 0.15–0.74) where adults with a more advantaged social grade (ABC1) had

less interest compared to adults from a less advantaged social grade (C2DE) (supplementary Table 4).

Discussion

Summary of findings

This study aimed to estimate the prevalence and characteristics of smokers in Great Britain interested in using VR generally and for encouraging and supporting smoking cessation. Despite VR being a relatively newer field of technology, half of smokers were interested in using VR generally. This mirrors the results of an online UK survey where 47% of adults in the general population were interested in experiencing VR [29]. Interest in VR specifically for encouraging or supporting smoking cessation was lower at 34.6%. This suggests that the diffusion of VR for general and entertainment purposes has been faster than the diffusion of VR for health purposes like smoking cessation. This is unsurprising given that diffusion of preventative technologies tends to be slower as their benefits are not immediate [14]. In a 2016 poll, UK consumers predicted that VR would have the most impact on video games and entertainment, followed by education and then healthcare [39].

Diffusion of innovations can occur unequally across different subgroups, and this can lead to digital exclusion. Digital exclusion is a combination of several factors including a lack of interest (not seeing technology as helpful or relevant), skills, and access to the internet and devices [18, 40]. In this study older respondents were much less likely to be interested in using VR generally, reflecting wider patterns in the digital divide [17, 18]. However, the proportion of respondents interested in VR specifically for smoking cessation was similar across all age groups except those 65 years and over, where the proportion significantly decreased, after adjustment for gender and social grade. These results are promising and suggest that a future smoking cessation VR intervention could be designed to appeal to and then be disseminated across a wide age group. While this study places adults over 65 in one age category, this group is not homogenous. A previous US study that looked exclusively at adults aged 65–103 also indicated that among the "oldest-old", age was associated with negative attitudes towards VR [41]. In contrast, in a Flemish study of adults over 56 years, attitudes towards VR were neutral before participants had ever used it, but became positive after use, suggesting that positive exposure to technology influences attitudes [42].

Some authors argue that efforts to increase interest in VR in older populations may only be warranted if it has a clear added value over non-digital methods [43]. While VR provides unique benefits (e.g., interactivity and immersive visual graphics), few studies have directly compared its long-term effectiveness to traditional smoking cessation interventions [7]. In contrast, others suggest that during the development of VR interventions, design considerations should accommodate older subgroups who may be interested in novel technologies but face other barriers regarding use. These design considerations include fall prevention, minimising cybersickness and accommodations for hearing and visual impairments [44]. As part of this study's wider project, co-design focus groups with smokers highlighted the need for user demonstrations to support those with limited digital skills [34]. Experts in smoking cessation and VR have also been consulted in focus groups to explore additional VR design factors needed for inclusivity.

Regarding other demographic factors and past digital health use, having used a digital smoking cessation aid in the past year was not associated with interest in VR generally or for smoking cessation. There was an association between higher educational attainment and interest in VR generally, but the association with interest in VR specifically for smoking cessation was uncertain. This suggests that people without post-16 qualifications may be excluded from this technology. Lower educational attainment has traditionally been associated with digital exclusion at large [45, 46]. In contrast, higher educational attainment typically correlates with the increased technological skills and digital literacy needed to operate devices. Also, educational institutions can provide access to devices [47]. Many authors have suggested working with members of subgroups who are at risk of digital exclusion during intervention development, with a focus on creating content that is easy to use across differing skill or educational levels [45].

Men were more likely to be interested in VR both generally and for smoking cessation. Previous survey data also suggested that a higher proportion of men than women were interested in experiencing VR (55% vs 40%) [29]. This gender gap may be because VR is mainly used to play video games, traditionally perceived as a male activity [48]. Review findings show that, with some exceptions, men are more likely to play video games [48]. There has been some debate regarding gender differences in smoking cessation. However, national survey data from Great Britain indicates that younger women (teenage years to forties) are more likely to quit smoking compared to men, although this trend reverses in the older age groups [49]. Also, survey data from England suggests that a higher percentage of women access formal smoking cessation services and treatments compared to men [50]. If VR is particularly appealing to younger men, a VR-based intervention could potentially address this gender inequality.

Additionally, respondents who were more motivated to quit, who had made previous quit attempts or who were currently cutting down on cigarettes were more likely to be interested in VR for smoking cessation. Similarly, one study found that UK and US smokers who were motivated to quit were more likely to have future intentions to use the internet or technology for smoking cessation compared to smokers unmotivated to quit [51]. Additionally, in another study, English smokers who were more motivated to quit and had made a quit attempt in the past year were more likely to express interest in using websites and apps for smoking cessation [52].

From a RE-AIM perspective (reach, efficacy, adoption, implementation, and maintenance) this paper provides the first estimate on the proportion of smokers who are interested in using VR for encouraging and supporting smoking cessation (34.6%), using a representative sample [10]. As of 2022, there are approximately 6.23 million smokers in Great Britain [1]. Therefore, a VR smoking cessation intervention could potentially reach up to 2,155,580 smokers in Great Britain (6,230,000 × 0.346). As more fully powered smoking cessation VR trials come to completion, this number could be used to estimate their potential public health impact if implemented on a wide scale (impact = reach x effect estimate) [53]. However, this calculation assumes that there will soon be wide-scale and equitable access to VR for those who are interested. Although government-commissioned reports demonstrate a level of national commitment to incorporating innovative technologies (including VR) into the national health service, wide-scale implementation will have considerable economic and human-resource implications [54, 55]. Therefore, we recommend that this estimate be interpreted with caution, and very much at the upper limit of possible reach. As part of this study's wider project, healthcare and smoking cessation professionals have been interviewed in focus groups to assess their views on VR and implementation barriers and facilitators.

An expression of interest in a survey does not necessarily reflect real-world uptake or engagement. For example, while 46.6% of English smokers expressed interest in using websites or smartphone applications for smoking cessation in 2011, later estimates for 2015–2018 indicated that only 2.7% of English smokers used a digital aid during their most recent quit attempt [22, 52]. This discrepancy between interest and uptake may be even more pronounced for VR. While ownership of smartphones in the UK is almost ubiquitous (approximately 94%), ownership of VR headsets is still relatively rare (4%) [13, 56]. The questions used to measure interest in this study specified that it was "free access" to a VR experience, to reduce the influence of current ownership levels and cost of purchase on responses. However, willingness to travel to get access to a free VR headset may influence responses as noted in the DAG. While the mainstream availability of VR for smoking cessation is still in its infancy, future research could investigate the factors influencing the relationship between interest and subsequent uptake at the individual level such as cost, availability, and awareness.

Strengths and limitations

To our knowledge, this is the first study to explore interest in VR in adult smokers. When looking at the adjusted association between age and interest in VR for smoking cessation, using a DAG provided transparency regarding the choice of confounding variables and made the proposed causal pathways explicit. Another strength of this study is the use of a nationally representative sample, which enhances the generalisability of the results. However, like other household surveys, the STS may not capture "hidden" populations such as those who are unhoused, in student accommodations, traveller communities or those in long-term care [57].

However, as mentioned previously, expressing interest in a survey may not correspond to future real-world uptake. Also, this paper was largely descriptive. Apart from the unplanned further analysis of the large association between age and interest, we did not adjust for any variables in the logistic regression and the individual odds ratios may be affected by confounding. Future work could use the results of this study to formulate hypotheses and inform a DAG and fully adjusted model for specific predictor variables, similar to this study's analysis of age.

The survey population in this study was restricted to smokers (i.e., cigarette and other tobacco users). While the Smoking Toolkit Study separately assesses the use of e-cigarettes and vapes, there may be some participants who interpreted the question assessing smoking status differently than intended – although the question explicitly asks them to exclude use of e-cigarettes and heated tobacco products. In England, it is estimated that the number of adults (smokers, ex-smokers and never-smokers) using e-cigarette or vaping devices long-term has increased from 1.3% in 2013 to 10% in 2023 [58]. While e-cigarettes are effective for smoking cessation, increased uptake in young never-smokers is a public health concern [59]. Although this study does not assess interest in using VR regarding vaping, a handful of VR interventions are in development which focus on vaping prevention and cessation in young people [60, 61].

Conclusions

Half of smokers are interested in VR generally and a third are interested in VR specifically for smoking cessation in Great Britain. Smokers who were men, more motivated to quit smoking, had made at least one past year quit attempt, were trying to cut down cigarettes or were interested in using VR generally were all more likely to be interested in using VR for smoking cessation. A VR smoking cessation intervention could potentially reach more than two million smokers in Great Britain. However, the results of this study indicated that reach would be higher in specific subgroups, such as men, younger and middle-aged smokers and those who are interested in quitting and trying to quit.

For age, after adjusting for social grade and gender, the odds of being interested in VR for smoking cessation were similar across all age groups, apart from those over 65, who had much lower odds, independent of social grade and gender. On the one hand, while VR's immersive and interactive features provide a unique opportunity for novel support methods, increasing interest in the oldest subgroups may not be crucial as long as other effective and non-digital cessation support is available. Conversely, it could be argued that more work should be done to avoid and examine digital exclusion in at-risk subgroups, such as those over 65. This could include qualitative research to explore barriers and facilitators of interest.

Abbreviations

VR	Virtual Reality
CET	Cue exposure therapy
RQ	Research question
STS	Smoking Toolkit Study
MTSS	Motivation to stop smoking scale
CI	Confidence intervals
OR	Odds ratios
DAG	Directed acyclic graph

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

T.O., D.K., O.P. and J.B. conceptualised the study. T.O. conducted the analysis and wrote the main draft, with D.K., O.P. and J.B. providing comments and edits. All authors reviewed and approved the final manuscript

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Data availability

The dataset analysed during the current study is available in the Open Science Framework repository, https://osf.io/ma675 [https://doi.org/10.17605/OSF.IO/GQTP2].

Declarations

Ethics approval and consent to participate

Ethical approval for the STS was granted originally by the UCL Ethics Committee (ID 0498/001). The data are not collected by UCL and are anonymized when received by UCL. All survey respondents gave informed consent to participate.

Consent for publication

Not applicable.

Competing interests

J.B. has received unrestricted funding to study smoking cessation from Pfizer and J&J who manufacture smoking cessation medications. All authors declare no financial links with the tobacco industry or their representatives.

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References

1. ONS. Adult smoking habits in the UK: 2022. 2023. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2022. Cited 2023 Oct 18.
2. WHO. Tobacco. 2023. Available from: https://www.who.int/news-room/fact-sheets/detail/tobacco. Cited 2024 Jan 15.
3. Marshall A-M, Siddiqui F, Dogar O. An evidence-based guide to smoking cessation therapies. J Prescrib Pract. 2023;5:324–33.
4. Kotsen C, Ostroff J, Carter-Harris L. e-Health Interventions for Tobacco Cessation. In: Breitbart WS, Butow PN, Jacobsen PB, Lam WWT, Lazenby M, Loscalzo MJ, editors. Psychooncology. Oxford University Press; 2021. p. 561–70.
5. Chow Y-W, Susilo W, Phillips JG, Baek J, Vlahu-Gjorgievska E. Video Games and Virtual Reality as Persuasive Technologies for Health Care: An Overview. J Wirel Mob Netw Ubiquitous Comput Dependable Appl. 2017;8:18–35.
6. Fox J, Arena D, Bailenson JN. Virtual Reality: A Survival Guide for the Social Scientist. J Media Psychol. 2009;21:95–113.
7. Keijsers M, Vega-Corredor MC, Tomintz M, Hoermann S. Virtual reality technology use in cigarette craving and smoking interventions (i "virtually" quit): Systematic review. J Med Internet Res. 2021;23:e24307.
8. Borrelli B, Rueras N, Jurasic M. Delivery of a smoking cessation induction intervention via virtual reality headset during a dental cleaning. Transl Behav Med. 2021;11:182–8.
9. Caponnetto P, Maglia M, Lombardo D, Demma S, Polosa R. The role of virtual reality intervention on young adult smokers' motivation to quit smoking: a feasibility and pilot study. J Addict Dis. 2018;37:217–26.

10. Glasgow RE, Vogt TM, Boles SM, Glasgow E. Evaluating the Public Health Impact of Health Promotion Interventions: The RE-AIM Framework. Am J Public Health. 1999;89:1322–7.
11. Rogers E. Diffusion of innovations. 4th ed. New York, NY: Free Press; 1995.
12. Angelov V, Petkov E, Shipkovenski G, Modern KT, Headsets VR. International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA). IEEE. 2020;2020:1–5.
13. Allen C. Understanding the VR market in 2021: Immersive Promotion Design. 2021. Available from: https://www.immersivepromotion.com/understanding-the-vr-market-in-2021. Cited 2023 Jan 26.
14. Rogers EM. Diffusion of preventive innovations. Addict Behav. 2002;27:989–93.
15. Bruce G. The VR activities consumers are most interested in. 2021. Available from: https://today.yougov.com/topics/technology/articles-reports/2021/04/14/watching-sports-shopping-picking-holiday-destination. Cited 2023 Jan 26.
16. Emmannuel Z. Mintel, Virtual Reality - UK - 2021. 2021. Available from: https://data.mintel.com/databook/1049099/. Cited 2023 Jan 26.
17. Davidson S. Digital Inclusion Evidence Review 2018. 2018. Available from: https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/age_uk_digital_inclusion_evidence_review_2018.pdf.
18. Stone E. Digital exclusion & health inequalities. 2021. Available from: https://www.goodthingsfoundation.org/insights/digital-exclusion-and-health-inequalities. Cited 2023 Jan 26.
19. Jordan H, Hidajat M, Payne N, Adams J, White M, Ben-Shlomo Y. What are older smokers' attitudes to quitting and how are they managed in primary care? An analysis of the cross-sectional English Smoking Toolkit Study. BMJ Open. 2017;7:e018150.
20. Vangeli E, Stapleton J, Smit ES, Borland R, West R. Predictors of attempts to stop smoking and their success in adult general population samples: a systematic review. Addiction. 2011;106:2110–21.
21. Kotz D, West R. Explaining the social gradient in smoking cessation: it's not in the trying, but in the succeeding. Tob Control. 2009;18:43–6.
22. Perski O, Jackson SE, Garnett C, West R, Brown J. Trends in and factors associated with the adoption of digital aids for smoking cessation and alcohol reduction: A population survey in England. Drug Alcohol Depend. 2019;205:e107653.
23. White M, Heywood P, Adams J. How and why do interventions that increase health overall widen inequalities within populations? In: Babones S, editor. Health, inequality and society. Bristol: Policy Press; 2009.
24. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ. 2007;335:806–8. Available from: https://doi.org/10.1136/bmj.39335.541782.AD.
25. Beard E, Brown J, West R, Acton C, Brennan A, Drummond C, et al. Protocol for a national monthly survey of alcohol use in England with 6-month follow-up: "The Alcohol Toolkit Study" Health behavior, health promotion and society. BMC Public Health. 2015;15:e230.
26. Fidler JA, Shahab L, West O, Jarvis MJ, McEwen A, Stapleton JA, et al. "The smoking toolkit study": a national study of smoking and smoking cessation in England. BMC Public Health. 2011;11:479.
27. Kock L, Shahab L, Moore G, Beard E, Bauld L, Reid G, et al. Protocol for expansion of an existing national monthly survey of smoking behaviour and alcohol use in England to Scotland and Wales: The Smoking and Alcohol Toolkit Study. Wellcome Open Res. 2021;6:67.
28. Kock L, Tattan-Birch H, Jackson S, Shahab L, Brown J. Socio-demographic, smoking and drinking characteristics in GB: A comparison of independent telephone and face-to-face Smoking and Alcohol Toolkit surveys conducted in March 2022. Qeios. 2022;
29. IPSOS. Ipsos Connect Virtual Reality Study 2016. 2016. Available from: https://www.ipsos.com/sites/default/files/2017-05/Ipsos_Connect_Virtual_Reality_Flyer_September_2016.pdf. Cited 2023 Jan 26.
30. Dhand N, Khatkar M. Statulator: An online statistical calculator. 2014. Available from: http://statulator.com/SampleSize/ss1P.html. Cited 2023 Jan 26.
31. IPSOS MediaCT. Social grade: A classification tool. 2009. Available from: https://www.ipsos.com/sites/default/files/publication/6800-03/MediaCT_thoughtpiece_Social_Grade_July09_V3_WEB.pdf. Cited 2023 Jan 26.
32. Kotz D, Brown J, West R. Predictive validity of the Motivation To Stop Scale (MTSS): A single-item measure of motivation to stop smoking. Drug Alcohol Depend. 2013;128:15–9.
33. Sharot T. Weighting survey results. J Mark Res Soc. 1986;28:269–84.
34. Okpako T, Kale D, Perski O, Brown J. Developing content for a virtual reality scenario that motivates quit attempts in adult smokers: A focus group study with art-based methods. PLOS Digital Health. 2024;3: e0000512.
35. Greenland S, Pearl J, Robins JM. Causal Diagrams for Epidemiologic Research. Epidemiol. 1999;10:37–48.
36. Byeon S, Lee W. Directed acyclic graphs for clinical research: a tutorial. J Minimal Inv Surg. 2023;26:97–107.
37. Textor J, van der Zander B, Gilthorpe MS, Liśkiewicz M, Ellison GTH. Robust causal inference using directed acyclic graphs: the R package 'dagitty.' Int J Epidemiol. 2016;45:1887–94.
38. Wang R, Ware JH. Detecting Moderator Effects Using Subgroup Analyses. Prev Sci. 2013;14:111–20.
39. Ambasna-Jones M. Work, rest & play: A report how virtual reality will impact everyday lives. 2016.
40. Honeyman M, Maguire D, Evans H, Davies A. Digital technology and health inequalities: a scoping review (2020). Cardiff: Public Health Wales NHS Trust; 2020.
41. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. Cyberpsychol Behav Soc Netw. 2023;26:886–95.
42. Huygelier H, Schraepen B, van Ee R, Vanden Abeele V, Gillebert CR. Acceptance of immersive head-mounted virtual reality in older adults. Sci Rep. 2019;9:4519.
43. Seifert A, Schlomann A. The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges. Front Virtual Real. 2021;2:e639718.
44. Ijaz K, Tran TTM, Kocaballi AB, Calvo RA, Berkovsky S, Ahmadpour N. Design Considerations for Immersive Virtual Reality Applications for Older Adults: A Scoping Review. Multimodal technologies and interaction. 2022;6:60.
45. Lee EWJ, McCloud RF, Viswanath K. Designing Effective eHealth Interventions for Underserved Groups: Five Lessons From a Decade of eHealth Intervention Design and Deployment. J Med Internet Res. 2022;24:e25419.
46. Sieck CJ, Sheon A, Ancker JS, Castek J, Callahan B, Siefer A. Digital inclusion as a social determinant of health. NPJ Digit Med. 2021;4:1–4.
47. Azzopardi-Muscat N, Sørensen K. Towards an equitable digital public health era: Promoting equity through a health literacy perspective. Eur J Public Health. 2019;29:13–7.
48. Veltri NF, Krasnova H, Baumann A, Kalayamthanam N. Gender Differences in Online Gaming: A Literature Review. Savannah: Twentieth Americas Conference on Information Systems. 2014.
49. Jarvis MJ, Cohen JE, Delnevo CD, Giovino GA. Dispelling myths about gender differences in smoking cessation: Population data from the USA. Canada and Britain Tob Control. 2013;22:356–60.
50. Kotz D, Fidler J, West R. Factors associated with the use of aids to cessation in English smokers. Addiction. 2009;104:1403–10.
51. Borrelli B, Bartlett YK, Tooley E, Armitage CJ, Wearden A. Prevalence and frequency of mHealth and eHealth use among US and UK smokers and differences by motivation to quit. J Med Internet Res. 2015;17:e164.
52. Brown J, Michie S, Raupach T, West R. Prevalence and characteristics of smokers interested in internet-based smoking cessation interventions: Cross-sectional findings from a national household survey. J Med Internet Res. 2013;15:e50.
53. Glasgow RE, Klesges LM, Dzewaltowski DA, Estabrooks PA, Vogt TM. Evaluating the impact of health promotion programs: Using the RE-AIM framework to form summary measures for decision making involving complex issues. Health Educ Res. 2006. p. 688–94.
54. Topol E. Preparing the healthcare workforce to deliver the digital future The Topol Review An independent report on behalf of the Secretary of State for Health and Social Care. 2019.
55. Kouijzer MMTE, Kip H, Bouman YHA, Kelders SM. Implementation of virtual reality in healthcare: a scoping review on the implementation process of virtual reality in various healthcare settings. Implement Sci Commun. 2023;4:1–29.

56. Laricchia F. Smartphone ownership penetration in the United Kingdom (UK) in 2012–2023, by age Statista. 2023. Available from: https://www.statista.com/statistics/271851/smartphone-owners-in-the-united-kingdom-uk-by-age/#:~:text=The%20smartphone%20penetration%20rate%20in,the%20highest%20smartphone%20penetration%20rate. Cited 2023 Sep 21.
57. Carr-Hill R. Finding and Counting Difficult to Reach Population Groups in the UK (and other Developed Countries). Int J Popul Data Sci. 2018;3:e067.
58. Jackson SE, Tattan-Birch H, Shahab L, Brown J. Trends in long term vaping among adults in England, 2013-23: population based study. BMJ. 2024;386:e079016.
59. Tattan-Birch H, Brown J, Shahab L, Beard E, Jackson SE. Trends in vaping and smoking following the rise of disposable e-cigarettes: a repeat cross-sectional study in England between 2016 and 2023. Lancet Reg Health - Eur. 2024;42:100924.
60. Xu Z, Dam L, Park S. Using Virtual Reality in E-Cigarette and Secondhand Aerosol Prevention Messages: Implications for Emotional Campaign Design. Cyberpsychol Behav Soc Netw. 2023;26:279–87.
61. Borrelli B. BU VapeChat Study. Available from:https://sites.bu.edu/vapechat/. Cited 2024 Sep 19.

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